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1832

Jerome Stillson

Chemical Instructor :

PRESENTING

A FAMILIAR METHOD OF TEACHING

THE

CHEMICAL PRINCIPLES

AND

OPERATIONS

OF THE MOST PRACTICAL UTILITY

TO FARMERS, MECHANICS, HOUSEKEEPERS AND PHYSICIANS ; AND MOST INTERESTING TO CLERGYMEN AND LAWYERS.

INTENDED FOR SCHOOLS AND THE POPULAR CLASS-ROOM.

THIRD EDITION.

BY AMOS EATON.

ALBANY :

PRINTED AND PUBLISHED BY WEBSTERS AND SKINNERS.

1828.

J. B. Stillson
Rochester, N. Y.

NORTHERN DISTRICT OF NEW-YORK.



BE IT REMEMBERED, That on the twentieth day of February, in the forty-sixth year of the independence of the United States of America, **WEBSTERS & SKINNERS**, of the said district, have deposited in this office the title of a book, the right whereof they claim as proprietors, in the words following, to wit :

" Chemical Instructor ; presenting a familiar method of teaching the Chemical Principles and Operations of the most practical utility to Farmers, Mechanics, Housekeepers and Physicians ; and most interesting to Clergymen and Lawyers. Intended for Schools and the Popular Class Room. By Amos Eaton.

In conformity to the act of the Congress of the United States, entitled " An act for the encouragement of learning, by securing the copies of maps, charts and books, to the authors and proprietors of such copies, during the times therein mentioned ;" and also to the act entitled " An act supplementary to an act entitled ' An act for the encouragement of learning ; by securing the copies of maps, charts and books, to the authors and proprietors of such copies, during the times therein mentioned,' and extending the benefits thereof to the arts of designing, engraving, and etching historical and other prints."

RICHARD R. LANSING,
Clerk of the N. District of New-York.

NOTICES

TO BE PREFIXED TO THE SECOND EDITION. QD 28
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1828

Although this is announced as the second edition, it might have been entitled the seventh; for it had been published, in substance, under the title of *Chemical Note-Book*, five times before it assumed the present form and title.

I believe it is known to all within the narrow limit of circulation, to which this book is destined, that I have devoted a large proportion of my time and attention to the simplification of chemical experiments, for the last nine years. During this period, I have given more than thirty full courses of lectures on chemistry, with from six to eight hundred experiments at each course; and have endeavoured to improve my method at every step in each course.

Every change which the reader will find in this edition, is the result of experience. All the experiments are described precisely as I have frequently performed them; and as I have often caused them to be performed by students in my presence.

The whole object of my course of instruction being the practical application of science to the common concerns of life, I give no experiments on rare, doubtful, or useless substances; and avoid, as far as possible, all hypothesis of a merely speculative kind.

The valuable works of Thompson, Ure, Brande, Murray, Accum, Henry, Davy, Gorham, and others; and the smaller works of Cotting, Cutbush, Comstock, &c. together with the translations of Lavoisier, Fourcroy, &c. as well as the essays, and editions of foreign works, published by Silliman, Cooper, Hare, &c. must all be contained in the library of the thorough chemist. But I venture to assert, that any one, or all, of these works will not form even a tolerable guide for a course of chem-

ical experiments adapted to the wants of the farmer, the mechanic, or the housekeeper. Neither is this such a work as I could wish to put into their hands ; but it comes as near it, as I am at present prepared to make it.

It is much to be regretted, that most of the latest celebrated treatises on chemistry, have so large a proportion of their pages devoted to those useless compounds, which can never profit the scholar nor the practical man. Particularly those endless compounds with chlorine and iodine, which may be equally multiplied and extended with any other substance. This is surely trifling with the richest stores of human knowledge. Put such works into the hands of a student, and tell him to place full confidence in the authors, he would form strange views of the science. He would imagine, that the chloridic and iodic theory of Davy constituted the whole science of chemistry ; and that all further knowledge of the subject should be pursued as a convenient, though not very important, appendage to chlorine and iodine. And even admitting all Davy's speculations to be well supported, are not those idle speculations as unimportant as any of the smallest mites of human knowledge ? I would as soon set a student to commit to memory all the amulets of the dark ages, or the number of ways in which the letters of the alphabet can be arranged.

In this edition I have prefixed a few general remarks, with a short account of the natural history, to each chemical principle. I have separated the *rationale* from the illustration, in the three first classes of chemical principles. The analysis of soils, minerals, mineral waters, &c. I have placed after organic substances.

A. EATON.

RENSSELAER SCHOOL,
Troy, N. Y. Feb. 6, 1826.

NOTICES

FOR THE THIRD EDITION.

As two full editions of this little book were sold in a very short time, without any exertion on the part of the bookseller or author ; its simple arrangement and quaint style seem to have been sanctioned. I shall therefore make no alteration in the plan, nor materially enlarge the book. A few corrections, and some extension of the head, *applications*, are nearly all the reader is to expect.

This enquiry has often been made : “ Since this little book is intended for schools and the popular class-room only, and has never been noticed in any public journal, why are more copies of it sold than of any other work on the subject of chemistry, published since it appeared ?

I answer this enquiry by an extract from a letter, written by the frank ingenuous professor of chemistry in one of our learned institutions.

“ I will thank you to request Messrs. Websters and Skinners to send me three dozen Chemical Instructors. For, like the professors of many of our public institutions, though Thompson, Brande, Henry, Graham, Davy, Murray, and other large books with great names, are set forth as the text-books, I conduct my lectures and give my experiments, according to your directions. Though I do not *acknowledge* myself dependent on this duodecimo of 260 pages ; yet it is my only safe guide for experiments. I intend now to put it into the hands of every student, with some sufficient apology to be borrowed from the neighboring professors.”

The professor in another public institution, says : “ I should not be able to go through with the labor of a course of chemical experiments, on account of my feeble state of health, had you not, by your simple

“method described in the Chemical Instructor, so
“greatly reduced the labor of preparation.”

I cannot consent to enlarge the work, according to the advice of some of my friends. I have long been convinced, that the greatest improvement which could now be made in our colleges, would be effected by introducing small text books, in which the substance of voluminous works should be judiciously condensed.

AMOS EATON.

Troy, March 28, 1828.

PORTABLE APPARATUS.

Pneumatic cistern. For an economical course of instruction, such as that proposed in the following work, a wooden box, three feet long, eighteen inches deep and eighteen inches wide, will be sufficient. It is made of pine plank, so arranged that the grains of the wood all run in the same direction; that all the pieces, constituting the cistern, may swell and shrink uniformly. Consequently, in the end pieces the grains are vertical.

Grooves are cut in the side pieces to let in the bottom and the end pieces. There is not a nail nor a pin used for holding it together. It is wholly secured by square iron rods with nuts and screws, resembling sleigh rods, with broad collars to prevent their sinking into the wood, and these are confined to the two side pieces. Four rods at each end and four under the bottom are sufficient. These may be loosened and tightened, by turning the nuts, as the planks swell and shrink. A lid is attached to one end of the cistern by strong iron hinges. This is very useful for covering up the cistern to prevent its freezing in cold weather, for the convenience of transportation, and to serve for a table when open.

The inside of the cistern is divided into two parts, by inch square posts, screwed to the side pieces within, and by a beam an inch and a half in depth and an inch thick resting upon, and screwed to the upper ends of the posts. The upper side of the beam is four inches lower than the top of the cistern. The smallest division is the well, and is half as large as the other; across which, with its ends supported on the said beam and a beam at the end, is the moveable shelf. This is three inches wide and two inches thick, having two inverted tunnels wrought in its under side, terminating upwards in small holes perforating the shelf. One of these holes is about three-fourths of an inch in diameter, which is generally used; the other is a quarter of an inch in diameter, furnished with a half-inch tube which is used for filling vials with gases. Shoulders are cut at each end of the shelf, letting it down so that it is but half an inch higher than the top of the beams; to prevent its rising up it is loaded with lead.

Common wooden water-pails, with wooden hoops, are used for gas-holders. Pails are selected of a size and height fitted to the size and depth of the cistern. The ears are cut off and one side of the top cut in a little, so as to permit water to enter, when they are inverted on the bottom of the cistern; for they are always used with their bottoms upwards. Each pail has a half-inch and quarter-inch hole in its bottom, for the admission of large and small stop-cocks, tubes, &c. These inverted pails may be held down in the water by cross-bars let into the sides of the cistern, or by a board cover. Such a cover may equal the size of all the surface of the cistern but the well, and form a level with the top of the moveable shelf. It may be perforated with auger-holes for admitting the necks of inverted decanters. Some of these holes may correspond with the holes in the pail-gasholder. These auger-holes are very convenient when decanters are used for collecting and holding gases, as a cheap and convenient substitute for bell-glasses.

A forge and furnace. Let a sheet-iron box be made, 12 inches long, 10 inches wide and 10 inches high. Let the corners be as nearly square, as the sheet-iron can be conveniently wrought. Let a hole be made

in one end about an inch in diameter, 3 inches above the bottom, for the admission of a bellows pipe. Place the neck for the stove pipe on the top, very near the opposite end. Cut an opening for a door in the middle of one side of the stove, nearly of a semi-circular form, with the strait side down, 3 inches above the bottom. Let its strait side be 6 inches, and the height 5 inches. Let the piece so cut be used for a door or lid, by shoving it up one inch, and supporting it at that height by 2 iron pins near the top of the opening on the outside, and two corresponding holes in the upper edge of the lid to suspend it by. Cut a hole one inch and a half in diameter, opposite to the centre of the base of the door, 2 inches above the bottom of the stove. A suitable length of pipe for conducting off the smoke under the mantle piece of a chimney or out at a window, finishes the iron part of the forge, which can always be borrowed for a course. A dripping pan, with a 3 inch brim, as large as can be put into the door, will be wanted for a sand bath. To use this apparatus, make a strong bench, about three feet high, and a few inches wider and longer than the box, and set it about 8 feet back of the cistern. Let it be so situated that every auditor can see an experiment at the nose of the bellows. Cover the bench with brick, and set the stove upon them. Set a row of brick edgewise around the inside of the stove. Bore a hole through two brick for the bellows pipe to go through. Then lay a floor of one thickness of brick inside of the stove, or box.

When a forge is wanted, put in the coal, leaving the door or lid off, and proceed as with other forges. When a sand bath is wanted, set in the dripping pan half filled with sand, supported on another lining of brick, with coal filled in. The heat under the pan may be regulated by the bellows; or the lid may be put up and a brick left off in front, when the inch opening under the lid will operate as an air furnace. It may be used as an air furnace for any other purposes in the same way. The sheet iron sides of the stove may be as easily defended with the loose brick, as if set in mortar. Be careful to keep a quantity of square-edged brick, squared on a grindstone, of equal dimensions.

A bellows. A large hand bellows is sufficient for any experiments. It may be fastened to a moveable stand or block, so that it will lie down steadily when used.

Tongs. One light pair of tongs, with the rivit near the bows, like taylor's shears; and one pair fitted both to hold a crucible and to pinch a small thing as a nail are sufficient.

Crucibles. Two large lead pots, with perforated bottoms, having tops large enough to take in a pint retort; and two or three nests of common crucibles.

Gun-barrels. Two gun-barrels at least, perfectly stopped at the brist, and air tight, will be wanted; for that which is kept for oxygen must not be used for carburetted hydrogen, nor for any other purpose, but collecting oxygen.

Gas-tubes. Two leaden tubes, drawn down to about one fourth of an inch caliber, long enough to reach from a gun-barrel set in the forge, to half across the cistern. A few lead and glass tubes will be wanted of various sizes.

Stop-cocks. About half a dozen good stop-cocks will be necessary. Small brass cocks at the hardware stores will do, if no better can be had, by filing off the crooked part.

Flexible tubes. These may be made of good calf-skin. Such tubes will not hold the gases, unless they are soaked in water three or four hours before they are used; or a shorter time if the water is moderately warmed.

Ladle and spoons. A common iron ladle, which will hold a pint or a little less. A common iron table spoon, a tea-spoon, and silver mustard spoon, very small.

Glass ware. 6 pint retorts, 6 half pint retorts, 2 half gallon bell-glasses, 2 quart bell-glasses, 2 tubulated quart bell-glasses, 6 assay glasses without feet or noses, sometimes called glass-cylinders, 2 bolt-heads or matrasses with 6 inch necks, 1 air thermometer, made like a bolt-head only more slender and delicate, a dozen test glasses, 2 dozen 8 ounce vials, 1 dozen plain pint and 1 dozen quart, decanters, an iron mortar, and a pint wedgewood mortar.

Borrowed glass ware, crockery, &c. Any liberal crockery merchant and druggist will lend the following articles, on condition they are paid for or returned clean and sound. 3 dozen plain wine glasses, 6 quart and 6 pint tumblers, 6 large and 6 small white earthen plates, 2 plain pitchers, 6 quart and 6 pint earthen bowls, 2 large wash bowls.

Mercurial trough. Get a mercurial trough cut in a block of wood about 9 inches long and 6 wide. Let it be cut 3 inches deep, 6 inches long, and so narrow as to hold 12 lb. of mercury, and leave an inch unfilled. A deep groove, for laying down a vial, in one side of the bottom. A druggist will lend the mercury, if the deficiency in weight be paid for.

Reflector. A plain sheet of tin for a reflector. Also a ball of iron with an eye to hang it by, for using with the reflector. See Caloric, Prop. 17.

Scales. An accurate pair of scales with grain weights.

Florence flasks. About two dozen.

Bags. About a dozen bladders for bags, large and small.

Kettle. A sheet iron kettle, holding about 3 quarts, with a handle on one side 18 inches long, and pouring nose on another side.

Dripping pan. An extra dripping pan, besides that used for a sand bath, and about 12 inches square, for holding coals, and for setting the lead pot in. This may be set on a couple of bricks laid on a table or bench, when coals are put in the pan, or when the lead pot contains coals and is set in it.

Jack-o'-lantern basin, for making phosphuretted hydrogen. See Phosphorus, Prop. 5.

Etching box. A box of tin (lead or copper is better,) two inches square and two inches high, open and perfectly even on the top. It

should be set in a hole in the centre of a tin plate, so that cold water may be poured on a piece of glass laid over its top, without wetting the coals on which the box stands. See Fluorine, Prop. 1.

Gas-pistol, for exploding gas, as directed under Hydrogen, Prop. 3.

Fire syringe. A syringe of lead, pewter, or other metal, six inches long and closed at the end. See Caloric, Prop. 2.

Hammers, files, a compass-saw, a block of wood for an anvil, wire of various sizes, gallipots, tobacco pipes, pincers, cork screws, and numerous other small articles will be wanted; which will occur to any instructor without particular directions.

USE OF APPARATUS.

The cistern is set firmly on short cross benches, elevated sufficiently to bring the top of it to the instructor's elbows. It is filled quite full of water. A tub stands under it with one edge projecting a few inches, directly under a large brass cock, which is fitted in, level with the inside bottom of the cistern. A long horizontal hole or slit is cut against the centre of the well, half an inch thick. A stopper is fitted to this, which may be pulled out to let the water run through it into the tub, when the experiments are of that kind which may cause the cistern to run over.

1. *Let each of the students fill the bell-glasses with water and set them on the shelves.* Hold a bell-glass, tumbler, cylinder, or specie bottle, in a horizontal position over the well. Sink it in this position until it is almost full, lower the closed end until all the air passes out; then turn the closed end upwards and raise it carefully, pressing it against the shelf until it is high enough to slide on the shelf.

2. *Let each student transfer air from one bell-glass to another.*

In this operation let the air be carefully poured up under water, into a glass filled with water so that no bubbles shall escape.

3. *Let each student pour air into the wooden gas-holder.*

In performing this operation, slide the vessel down against the gas-holder, keeping it in a vertical position until it reaches the bottom of the cistern. Then incline it towards the horizontal position, and at the same time raise the gas-holder; and crowd it gradually into the gas-holder.

4. *Let each student pass a current of air from a gas-holder by way of a stop-cock through a lead tube.*

A stop cock is fitted into one of the holes of a gas-holder (the other hole being stopped with a peg,) and the gas-holder is afterwards filled with air by blowing the air under it through a tube. The gas-holder being filled, press it down to the bottom of the cistern, and stay it there.

Fix a lead tube to the stop-cock, and turn the stop. A strong current will be forced out by the pressure of the water of the cistern into the gas-holder below.

5. *Let each student pass a current of air from a gas-holder through a flexible tube and tobacco-pipe, and make soap bubbles.*

Perform this operation as directed under Hyd Prop 7.

6. *Let each student fill a small glass cylinder, invert it and set it on the shelf of the mercurial trough.*

This operation is performed as directed with water. But requires that the glass cylinder be grasped firmly and held steadily.

7. *Let each student use a retort by passing a common gas into a receiver.*

In performing this experiment, let the student produce hydrogen, as directed under Hyd. Prop. 1.

8. *Let each student take the specific gravity of a mineral.*

Weigh a small mineral specimen in the air, suspended from a beam of the scales by a fine silk thread. Then let it hang in a tumbler of water and weigh it there. Now subtract the weight in water from the weight in air, and divide the weight in the air by the difference, and the quotient will be the specific gravity.

CHEMICAL SUBSTANCES,

FOR A COURSE OF EXPERIMENTS.

Tests for acids and alkalis. Collect in the month of October or November, leaves from the red cabbage. Those of the brightest red are not the best; but those should be selected, which are rather bluish or glaucous. Dry the thinnest part of the leaves, or the bark of the stalk, by slow heat of a fire or stove. The heat should not be sufficient to dry them in less than four or five days. When dried sufficiently break them up pretty fine by rubbing them in the hands, and cork them up in dry phials. When wanted for use put about a tea-spoonful into a wine-glass of pure rain or river water, and soak it about an hour. Then press it with a rod and pour off the water into another wine-glass or phial for use. It should never be used after the infusion has been made longer than two or three days.

Procure at the shops, or elsewhere, the following substances for one course of lectures.

Sulphuric acid 2 quarts, nitric acid 1 pint, muriatic acid 1 pint, iron filings at the gun smith's 2 pounds, phosphorus 1 ounce, oxymuriate of potash 1 ounce, sulphur 1 roll, sea coal 3 pounds, hard soap 1 pound, chalk 2 pounds, carbonate of ammonia 1 pound, muriate of ammonia 4 ounces, oxyd of manganese 10 pounds, saltpetre 1 pound, red lead 1 pound, pearl ash 2 pounds, quicklime 6 pounds, fine table salt 2 quarts, white wax 1 cake, borax 2 ounces, fluor spar 6 ounces, carbonate of soda 3 ounces, liquid ammonia 8 ounces, copperas 8 ounces, blue vitriol 2 ounces, alum 2 ounces, white vitriol 1 ounce, magnesia of the shops 2 ounces, epsom salts 6 ounces, sugar of lead 2 ounces, corrosive sublimate 1 ounce, calomel 1 ounce, lunar caustic quarter of an ounce, verdigris 2 ounces, nut galls 2, prussiate of potash quarter of an ounce, spirits of turpentine 1 pint, oxalic acid quarter of an ounce, or it may be obtained in the expressed juice of green wood-sorrel, alcohol 1 pint, ether 1 ounce. A little zinc, tin foil and grain tin, bismuth, gold leaf,

arsenic, copper filings and lead. Also a little gum-arabic, starch, white sugar, sweet oil, rosin, camphor, liquorice in ball, india rubber, indigo, prussian blue, flowers of benzoin, citric acid, vinegar, glue, isinglass, iodine, sulphuric ether, nitrate or muriate of barytes and strontian, chromate of potash, zaffre, silver leaf, platina wire, best potter's clay, tobacco pipes, a coil of wax tapers, common potash, a pound of tow, 3 pounds of putty for lutes, gun flints, 3 sizes of iron and brass wire.

It is best to put all these articles into phials, boxes, and paper bags, shut closely; and have them all labelled and well arranged.

COURSE OF LECTURES.

Divide the course into thirty lectures. Each lecture should occupy one hour. If a very full course is required, one hour and forty minutes. If a hasty illustration of general principles is required, half an hour to a lecture is sufficient, and two half hour lectures may be given each day. Let the subject of each lecture be as follows:

1st lecture to include Affinity.	18th, Lime.
2d, first half of Caloric.	19th, Barytes, Strontian, Magnesia and Silica.
3d, last half of Caloric.	20th, Alumina, and Metals in general.
4th, Electricity and Light.	21st, Iron, Manganese and Tin.
5th, Oxygen, and the Nomenclature.	22d, Zinc, Arsenic and Chrome.
6th, Chlorine gas.	23d, Copper, Antimony, Bismuth and Cobalt.
7th, Muriatic acid, Fluorine, and Iodine.	24th, Gold, Silver and Platina.
8th, first half of Hydrogen.	25th, Mercury, Lead, and Nickel.
9th, last half of Hydrogen.	26th, Vegetable Substances.
10th, first half of Nitrogen.	27th, Animal Substances and Dyeing.
11th, last half of Nitrogen.	28th, Analysis of Mineral Waters and Soils.
12th, Sulphur.	29th, first half of Analysis of Minerals.
13th, Phosphorus.	30th, last half of Analysis of Minerals.
14th, first half of Carbon.	
15th, last half of Carbon, & Boron.	
16th, Potash, and the Nomenclature.	
17th, Soda and Ammonia.	

CLASSIFICATION

OF

CHEMICAL PRINCIPLES.



IN the present state of chemical science, it is supposed that we have fifty-six chemical principles ; and that each of these principles, excepting affinity, is a simple material substance, differing in some essential qualities from all the others.—Eighteen of these are either very uncommon or of a doubtful nature, or unmanageable in the arts. *Only thirty-seven of the simple substances are used in the arts or in agriculture.* As all animal and vegetable matter, all soils, all works of art, and every thing with which we are concerned in life, consist of one, two, or more of the thirty-seven simple substances, which are printed in italics in the following list, they may be considered as the chief subjects for the attention of the student in chemistry

Chemical principles are distributed into five classes.

CLASS 1. POWERS.

*Affinity, *Caloric, Electricity, Light.*

CLASS 2. ACIDIFYING SUBSTANCES.

Oxygen, †Chlorine ? Fluorine ? Iodine ?

* This is an universal *property* of matter.

† I do not believe, that either of these three last is a simple or acidifying substance. But I am compelled to submit to the force of authority.

CLASS 3. OXYDABLE SUBSTANCES, NOT METALLIC.

Hydrogen, Nitrogen, Sulphur, Phosphorus, Carbon, Boron, Selenium.

CLASS 4. METALLOIDS.

Section 1. The bases of alkalis and of alkaline earths. Of *Potash*, of *Soda*, of *Lime*, of *Barytes*, of *Strontian*, of *Magnesia*, of *Lithia*.

Section 2. The imaginary bases of non-alkaline earths. Of *Silex*, of *Alumine*, of *Glycine*, of *Zircon*, of *Yttria*, of *Thorina*.

CLASS 5. METALS.

Section 1. Those which absorb oxygen with such force as to decompose water when heated sufficiently. *Iron, Manganese, Tin, Zinc, Cadmium.*

Section 2. Those which absorb oxygen, but not with sufficient force to decompose water, and from which oxygen cannot be separated by heat alone. (Some are capable of becoming acids.) *Arsenic, Chrome, Molybdena, Tungsten, Columbium.* (Others are not capable of becoming acids.) *Copper, Antimony, Bismuth, Cobalt, Titanium, Tellurium, Cerium, Uranium.*

Section 3. Those which receive oxygen artificially from the decomposition of strong acids only. *Gold, Silver, Platina, Palladium, Osmium, Rhodium, Iridium.*

Section 4. Those which absorb oxygen at limited temperatures, and give it wholly off at higher temperatures. *Mercury, Lead, Nickel.*

ORGANIC SUBSTANCES.

All vegetable and animal bodies have for their ultimate elements three or more of the preceding simple substances. Carbon, oxygen and hydrogen are essential to vegetable matter. Carbon, oxygen, hydrogen and nitrogen, are essential to animal matter. Other simple elements are, in almost all cases, combined with these.

PROXIMATE ELEMENTS.

Those substances which are produced in plants and animals by the common operations of nature, are denominated proximate principles, or proximate elements.

Of Plants. Gum, resin, gum-resin, fixed oil, volatile oil, starch, gluten, albumen, fibrin, gelatine, bitter principle, extractive matter, tannin, wax, camphor, sugar, guaiacum, balsam, caoutchouc, indigo. These are the most important. Several others are described in authors; besides the vegetable acids, which will be noticed hereafter.

Of Animals. Gelatine, albumen, fibrin, gaseous matter, &c. which will also be described hereafter.

All compounds in the mineral kingdom, as amber, bitumen, &c. and all the aerological compounds, as the atmosphere, and the various vapours and compound gases which float in it, and all other material compounds of which we have any knowledge, consist wholly of a greater or less number of the chemical principles enumerated in the five classes.

CLASSES OF CHEMICAL PRINCIPLES.

CLASS I. POWERS.

PRINCIPLE 1. AFFINITY.

Natural History and general Remarks.

The term Natural History is considerably distorted in applying it to this class of chemical principles. This liberty is taken here for the sake of uniformity.

Affinity is an universal property of matter ; consequently it is in all places where matter is found. Though the other three powers are supposed to be matter by most chemists, affinity is not held to be so by any. It is one of the five kinds, or, as some express it, one of the five modifications of attraction. The other four, viz. of cohesion or adhesion, of gravitation or electricity, and of magnetism, appertain to the department of Natural Philosophy. Being the only kind of attraction which is employed as an efficient agent or power in producing chemical changes, it is called chemical attraction.

The term affinity is limited exclusively to heterogeneous attraction ; that is, when dissimilar particles or atoms are compounded together. Homogeneous attraction, or that application of attraction, whereby similar particles are held together, as the constituent particles of a bar of wrought iron, should be placed under cohesive attraction.

Affinity is simple or elective in its effects, according to its applications ; though the principle is a single one and uniform in its operations.

✓ Proposition 1. *Simple affinity is that application of affinity or chemical attraction, whereby the*

constituent atoms of a compound body are united, without causing any decomposition.

Illustration. Pour a teaspoon of olive oil into half a wine glass of water. No combination will take place. Drop in a piece of pearlash, half the size of a pigeon's egg, let it dissolve and stir the mixture, which will effect a chemical combination, and produce white soap.

Rationale. Water and oil repel each other; therefore these two substances, on being mixed, illustrate the absence of affinity. All alkalies (of which potash, the basis of pearlash, is one) attract both water and oil. Consequently it operates as the bond of union between the water and oil. While this union is effected nothing is excluded. No decomposition having taken place, the experiment has been performed by simple affinity.

Application. By the application of this principle, soft soap is manufactured with oil (or soap-grease) potash and water—Hard soap with oil, soda and water. Also volatile liniment with ammonia, olive oil and water. Sulphuric acid (oil of vitriol) by the direct combination of sulphur and oxygen.

Elective affinity is either single or double.

Prop. 2. *Single elective affinity is that application of affinity, whereby the constituent atoms of a new compound, by the force of their attraction, exclude others from a previous state of combination.*

Illustration. Put a teaspoon of table salt into a wine glass, which had been previously dried on a plate. Pour upon it a teaspoon of sulphuric

acid. Muriatic acid gas will escape into the atmosphere, and Glauber's salts will be formed in the wine glass.

Rationale. Table salt consists of muriatic acid and soda. Soda has a stronger affinity for sulphuric acid than for muriatic. It therefore elects the sulphuric acid, and unites with it with such force, as to exclude the muriatic. Such is the nature of the muriatic acid that when separated from its combination with other substances, it becomes a gas and enters into the atmosphere. It is invisible, but by its attraction for water it unites together, or condenses, the aqueous vapour of the atmosphere so as to render the vapour visible. By the visibility of the vapour we perceive the course and motions of the gas.

Application. On this principle soda is obtained from common salt for the manufacture of coarse hard soap. The muriatic acid of the salt elects the potash which is introduced, and the soda of the salt being excluded, immediately unites to the animal oil and forms with it the hard soap. See this process more fully explained under soda.

Prop. 3. *Double elective affinity is that application of affinity whereby neutral compounds decompose each other and form other neutral compounds.*

Illustration. Take about four parts of muriate of lime and five parts of sulphate of soda, weighing them after being well dried over coals on plates. Dissolve them in water separately. Now mix them in a wine glass, and a precipitate of sulphate of lime (gypsum) will soon settle at the bottom, and a solution of muriate of soda will stand over it. On testing the new compounds with red

cabbage, they will be found to be neutral salts—exhibiting neither the acid nor alkaline test. On tasting the liquid it will be found to be a solution of table salt.

If the proportions of sulphate of soda and muriate of lime are mixed at random, after being dissolved, without weighing or measuring, the result will be pretty satisfactory, provided the muriate of lime be in excess. Sulphate of lime will be precipitated, and the supernatant liquid will be a mixture of muriate of lime and muriate of soda. The muriate of lime being almost tasteless, the new formed muriate of soda will be readily recognized.

Rationale. Though the sulphuric acid and muriatic acid both have a stronger affinity for the soda than for the lime, and though the soda has a stronger affinity for the sulphuric than for the muriatic; yet the attraction between the lime and the muriatic acid being comparatively feeble, and pretty strong between the sulphuric acid and the lime, and between the muriatic acid and the soda, the sulphuric acid being hard pressed by the effort made by the muriatic acid and soda to unite, is drawn away by the lime from the soda, leaving the muriatic acid in possession.

Application. Corrosive sublimate of the shops is made upon this principle by sulphate of mercury and muriate of soda, as will be shown under mercury. Numerous other operations will be referred to this principle under the various bases of numerous compounds. Upon this law Dr. Wollaston constructed a scale of chemical equivalents, by which the artist or the chemist can at sight determine what proportions of any com-

pounds are required for decomposing each other without loss. For if the proportions be found, between the quantities of the bases necessary for saturating any one acid, the same relative proportions of the same substances will be required for saturating all other acids. Or if the proportional quantities of acids required for any one base be determined, the same relative proportions of acids will be required for all other bases. These relative proportions of acids or alkalies, are denominated equivalents to each other. For example ; if a given quantity of sulphuric acid should require for saturation three times as much potash as alumine, then it would follow of course that nitric acid and muriatic acid would require three times as much potash as alumine for saturation ; though all these acids would differ from each other in the absolute quantity required.

Prop. 4. By affinity the constituents of compounds are united in definite proportions, in all cases wherein the properties and sensible qualities are thereby changed.

Illustration. Put into two wine glasses half a teaspoon of muriatic acid to each. Put a solid mass of carbonate of soda into each, of equal weight, and in such quantity as to be beyond what is sufficient to saturate the acid. After effervescence ceases weigh what remains of each parcel and they will be found to be equal. Pass about the liquids in the two wine glasses, with tasting rods (pine sticks are as good as glass rods) and the taste of common table salt will be recognized by all.

Rationale. The soda of carbonate of soda has a stronger affinity for muriatic acid than for the

carbonic ; consequently it unites to the muriatic acid and forms common table salt, (muriate of soda.) The effervescence is caused by the escape of the carbonic acid, which was a constituent of the carbonate of soda. This union of the soda with the portions of muriatic acid would continue an unlimited time, were it not for the law of definite proportions. That the proportions are definite is manifest from the fact, that in both trials the same quantity of soda is required for the same quantity of acid. At this definite point, the caustic alkali (soda) and the severe acid, (muriatic) become common table salt.

Application. The law of definite proportions is of great importance in the arts. It regulates the uniformity of compound bodies, and prevents the evils which might arise from carelessness or mistake in the manufacture of many articles. In the manufacture of copperas for example, 36 parts of the protoxyd of iron will unite with precisely 40 parts of sulphuric acid. And in the manufacture of white vitriol, 42 parts of oxyd of zinc will unite with 40 parts of sulphuric acid. These are the uniform proportions in the dry state ; and each takes 63 parts of water for crystallization. Therefore if the manufacturer should carelessly add too much acid or too much metal, he would suffer a loss of the material in excess, but nature would impose this law upon him and compel him to give us copperas in the one case and white vitriol in the other, notwithstanding his errors.

Prop. 5. *By affinity some substances unite with other substances in several definite proportions, which proportions can always be expressed in whole numbers without any fractional remainder.*

Illustration. [This experiment cannot be given during a lecture before a class.] Take any quantity of nitric acid, and, by a process to be given under nitrogen, reduce it down, by taking away portions of oxygen, to nitrous acid, hyponitrous acid, deutoxyd of nitrogen (nitric oxyd) and protoxyd of nitrogen (nitrous oxyd, or exhilarating gas) and the proportions of oxygen combined with nitrogen in each state of combination will be found thus—In the protoxyd of nitrogen 175 grains of nitrogen will be combined with 100 grains of oxygen—in deutoxyd of nitrogen 175 grains of nitrogen with 200 of oxygen—in the hyponitrous acid 175 grains of nitrogen with 300 of oxygen—in the nitrous acid 175 grains of nitrogen with 400 of oxygen—in the nitric acid 175 grains of nitrogen with 500 of oxygen.

Rationale. Nature having, in the case of the nitric acid of saltpetre combined with nitrogen the highest proportion of oxygen which it will receive, and it being extremely difficult to combine nitrogen and oxygen chemically, it is necessary to begin with this high combination and reduce the oxygen down to its lowest proportion. Then on retracing our steps, we find the proportions rising in a numeric ratio. The same rule has been found to govern in all combinations where sufficient investigation has been made.

Application. The ATOMIC THEORY is founded upon the above fact. Mr. Dalton infers, and supports his inference with great ability, that the ultimate atoms of these compounds are numerically combined. For example, that if the ultimate atom of oxygen is supposed to weigh one, the ultimate atom of nitrogen weighs one and three

fourths. Then one atom of nitrogen and one atom of oxygen, form the smallest particle of the protoxyd of nitrogen (exhilarating gas)—that one atom of nitrogen joined to two atoms of oxygen form the smallest particle of the deutoxyd of nitrogen—one atom of nitrogen to three of oxygen form the hyponitrous acid—one atom of nitrogen to four of oxygen form the nitrous acid—one of nitrogen to five of oxygen form the nitric acid (aqua fortis.) See M'Nevin's Atomic Theory—also Thompson, Brande, Ure, and Gorham.

Prop. 6. By affinity some substances unite in indefinite proportions; and their properties and sensible qualities are not changed.

Illustration. Mix alcohol and water, or sulphuric acid and water. The qualities and sensible properties of both these liquids will remain unchanged. Being diffused among the water, there will be less of them in a given measure or space, but they will remain unchanged.

Rationale. The combination is not a mere mechanical suspension like clay diffused in water, because they will never settle down at the bottom of the water. It must therefore be a chemical compound; though very different from that described in the 4th proposition.

Application. Proof spirit, brandy, gin, &c. are made by combining alcohol with water. If more water is added, as in forming what is called grog, still the alcohol is not changed. Caloric unites with ice, forming water, and with water forming steam, without changing the nature of the water. But the proportion is definite for changing ice to water and water to steam; and here the change

of the state of it seems to bear a suitable proportion to the definite proportion of caloric.

Prop. 7. *Heat increases the strength of chemical affinity.*

Illustration. Pour cold nitric acid, diluted with about an equal measure of water, upon lead shavings in a florence flask, and little or no action will take place. Set the flask containing the lead and acid upon hot coals, or over a candle or lamp, action will commence, exhibiting the orange fumes of nitrous acid, &c.

Rationale. Lead attracts the oxygen of the nitric acid very feebly when cold. When heated its attraction encreases in strength, and it takes so much oxygen from the nitric acid, that the acid is reduced which comes in contact with the lead, producing the orange gas. The process of reducing nitric acid is fully explained under nitric acid and nitrous acid.

Application. This principle has an almost perpetual application in the manipulations of the laboratory, and in many of the arts. In the manufacture of soap, though it may be made cold, the encreased affinities by the aid of heat, greatly expedite the combination of the oil and alkalies. In the manufacture of sulphuric acid, the affinity between sulphur and oxygen is never sufficient without the aid of heat.

Remark. In some cases elective affinity is considerably varied by varying the proportion of the masses of substances presented to each other.—That is, the weaker affinity may be strengthened by increasing the quantity of the substance possessing the weaker affinity. This complicated

subject is ably treated by Berthollet in his researches into the laws of chemical affinity. Also see Gorham's article Affinity.

Prop. 8. In some cases affinity is strengthened between two bodies by combining one of them with some other body.

Illustration. Put copper filings into a vial of pure oxygen gas, and they will not unite. Put them into a wine glass of nitric acid, and they will immediately become oxydated.

Rationale. Though pure oxygen will not combine with copper, a proportion of it will separate from its combination with nitrogen in the nitric acid, and unite with the copper; thereby reducing nitric acid to nitrous acid, called the orange gas. This gas will be seen ascending from the wine glass.

Application. In the manufacture of hard soap, which consists of animal or vegetable oil and soda, the two substances will not unite without boiling together a long time. But if the manufacturer first unites the oil with potash, and then introduces muriate of soda; when the potash separates from the oil to unite with the muriatic acid, the soda, of the muriate of soda, unites almost instantaneously with the oil.

PRINCIPLE 2. CALORIC.

Natural History and general Remarks.

Caloric is contained in every body constituting the earth, and whatever exists upon and near its surface. It is probably diffused throughout the solar system, and even throughout the universe. The coldest ice, the hardest metal, as well as the

most expanded gas, all contain caloric in combination. Steam contains caloric. Abstract caloric until but 212 degrees, according to Fahrenheit's scale, remain, and it will become water. Take away 180 degrees more, leaving but 32, and it will become ice. Continue to abstract more and more, until the known powers of nature and of art are exhausted in the operation, and there will still remain an immeasurable proportion of caloric in combination with the ice.

All gases and liquids would become solids, if caloric were abstracted to a certain degree. Atmospheric air would first become liquid, liquids would become solids, till, at length, all things would become as permanently solid as the oldest primitive rocks. But on increasing the quantity of caloric in the whole terrestrial system, all solids would become liquids, and liquids would become gases. Rocks would become fused, and at length be converted into gases. By continually adding caloric, the whole substance of the earth and its inhabitants, would become a vast globe of rarified gas. Hence it follows, that all substances are capable of being in the state of a solid, of a liquid, or of a gas; and that these states depend on the quantity of caloric held in combination. See Lavoisier's Elements.

Proposition 1. Caloric and light are not the same substance.

Illustration. Suspend an iron ball, which is at a high red heat, by a wire, opposite to a sheet of white paper pinned to the wall, and at the distance of about four feet from it. Place an air thermometer between the ball and the paper, five or six inches from the paper. After the liquid in

the thermometer has been moved down by the heated ball as much as the heat will move it, darken the room. Now bring a pane of clear glass before the ball, at the distance of about six inches from it. The liquid in the thermometer will immediately rise, while the light thrown upon the paper will not be materially diminished by the interposition of the glass.

Rationale. Caloric and light are both radiated from the heated ball. The thermometer is affected by the caloric, and the paper is illuminated by the light. If light and heat are the same substance both should be equally interrupted by the interposed glass. But since the heat is greatly interrupted, and the light not materially interrupted (unless it be by some imperfection in the glass,) it follows, that they possess different properties, and cannot be the same substance.

Application. A glass screen will defend the face and eyes from heat, when we inspect iron or other metal in a state of fusion with a magnifier of two or three inches focus.

Prop. 2. *Combined caloric, which does not excite the sensation of heat nor affect the thermometer, may be brought to the free state by compression.*

Illustration. Put a piece of tinder in the end of the piston of the fire syringe, consisting of cotton cloth dipped in a solution of saltpetre and well dried. Force down the piston suddenly, and the tinder will take fire.

Rationale. Caloric was combined with the air in the syringe before it was compressed; in which state it did not excite the sensation of heat nor in-

flame the tinder. When it was compressed by the piston, the particles of air were brought too near each other to afford room for so much caloric. Part of it being forced from its state of combination, became free and inflamed the tinder.

Application. There is so much caloric in the combination with air, water, and other substances about us, that if it were capable of producing the ordinary effects of heat, the whole race of man would be burned to cinder in a day.*

Prop. 3. *Combined caloric may be brought to the free state by mixing liquids which strongly attract each other.*

Illustration. Set a wine glass, half filled with cold water, within about half an inch of the bulb of an air thermometer. Set another wine glass equally near, half filled with cold sulphuric acid. Let them stand a few minutes. Now empty the glass of sulphuric acid into the water, and the air in the thermometer will be considerably expanded.

Rationale. In this experiment, the caloric remains combined with both liquids while they are separate; and the thermometer is not affected. But when they are mixed, the affinity between sulphuric acid and water unites them so closely as to diminish their bulk, and to force part of their caloric from the combined to the free state. It then passes off towards other bodies, and in its

* Some chemists consider heat as the effect of a *vibratory motion* in the particles of matter. This hypothesis is chiefly founded upon the fact, that a flame may be excited and continued by friction, greatly disproportioned to the combustible substances consumed. But was this experiment ever fairly made in the exhausted receiver of the air pump? If a stick is put in the state of rapid rotary motion in a lathe, and another stick held against it, a great flame will be produced, by the compression of the air which is forced between the sticks by this rapid motion.

way passes into and expands the air of the thermometer.

If the hand be applied to the wine glasses before and after the mixture of the liquids, it will appear, that while combined with the liquids the caloric does not excite the sensation of heat; but that when pressed out into a free state by the mixture, it does produce that sensation.

Application. When we sit by a fire we are warmed by the caloric, which is brought out from its combined state with the oxygen of the atmosphere, into a free state, through the agency of the combustible fuel. Here is no addition of caloric; for the air of the room held all, which now warms us, in combination, before we experienced that sensation.

Prop. 4. Caloric, by entering into combination with solids in due proportion, may convert them into liquids, and by encreasing the proportion, may convert the liquids into vapours or gases.

Illustration. Lay a piece of ice on a hot stove or fire-shovel, it will soon receive caloric sufficient to become water. Let it remain a little longer and it will become vapour and pass off into the air.

Rationale. The particles of water in the state of ice were fixed; but caloric being introduced between them caused them to move freely among each other, and thus become liquid. More caloric being introduced, the particles were separated so widely as to form vapour or steam.

Application. When a kettle of water is placed over the fire, the particles of water next to the bottom first receive caloric enough to become vapour or steam, and attempt to ascend; but the colder

water above robs them of a portion of caloric and forces them to remain in the liquid state. When all the water in the kettle has received very nearly the quantity of caloric required for converting the whole into vapour, the particles next to the bottom being converted into steam succeed in ascending to the top and passing off. A succession of such ascending particles of vapour keeps up the bubbling called boiling.

Metals are fused upon the same principle. The same cause also keeps the atmosphere in the state of gas.

Prop. 5. More caloric is required for converting liquids into vapour or gas, when the liquids are subject to atmospheric pressure, than when that pressure, or any part of it, is taken off.

Illustration. Fill a florence flask one third full of water. Fit a sound cork to its mouth perfectly tight. Suspend the flask with the mouth open, over a candle, lamp, or coals, until the water boils. Put in the cork, that all air may be excluded which is driven out by the steam, before the flask is taken down. As soon as the water stops boiling, set the flask on ice, snow, or in cold water, and it will instantly boil. Hold it over the coals and it will not boil. This may be repeated a dozen times with success. The flask may be passed through fifty hands after it is so cool as not to be painful to the hand, and then be returned, and still boil when set on ice, snow, or in very cold water.

Rationale. Water does not require 212 degrees of heat for converting it into vapour. It has been made to boil at 67 degrees ; that is 31 de-

degrees below blood heat. Therefore it requires 145 degrees of heat to resist the pressure of the atmosphere. In this experiment the atmospheric pressure is taken off, or most of it, and the water is left to boil with the degree of heat which it requires when not restrained by atmospheric pressure.

Application. A boiling pot which boils over with the lid on, will often cease to boil over when the lid is removed. In this case there is not a vacuum between the lid and the water; but the air beneath the lid being driven out by steam, leaves room, without the usual pressure, for the steam continually to follow it to the top of the pot, so as to pass out under the edges of the lid. When the lid is taken off, the pressure of the atmosphere keeps down the water until an additional degree of caloric forces it up again. It cannot be said that the cold air which is let in, by cooling the water, produces this effect; for it will not, if the heat is but about 212, boil over again with the same fire. A stronger heat is now required.

Prop. 6. *Caloric enlarges the volume, and thereby diminishes the specific gravity of a gas, by entering into and combining with it.*

Illustration. Bring a burning coal near an air thermometer, and it will force the liquid down the tube.

Rationale. Caloric being accumulated in one body in excess, compared with the quantity of it in another body, in seeking its equilibrium passes into the body containing the less quantity. Thus it passes from the burning coal into the atmosphere about it, including the atmospheric air in

the bulb of the air thermometer. This enlarges the volume and forces the liquid down, and out at the mouth of the beak of the thermometer.

Application. A heated chimney or stove pipe, by thus expanding the air in it, renders it of less specific gravity than the surrounding air. The heavier air presses into it of course; and thus a current, carrying with it smoke, &c. is continued in that direction. The same application of caloric, on a vast scale, causes winds.

Prop. 7. *Caloric passes from its combination with one body into another, which contains less in proportion to its capacity for caloric, until the two bodies are in equilibrio.*

Illustration. Put the warm hand upon the bulb of the air thermometer, and the liquid will sink at first and at length become stationary. Dip the hand in cold water and it will rise.

Rationale. The hand containing more caloric, in proportion to its capacity for caloric, than the air in the thermometer, caloric passes out of it and enlarges the volume. When the hand is cooled, the order is inverted.

Application. Frozen eggs or apples are thus gradually thawed in cold water. Water, not being frozen, though very cold, contains more caloric than they; consequently caloric passes gradually into them from the water until their temperature is raised above freezing. When the hands or feet are frozen, they should be gradually thawed in cold water in the same way.

Prop. 8. *Caloric expands liquids, as well as gases, by entering into and combining with them.*

Illustration. Take the measure of the length

of a cold rod of iron, which is about a foot long and cut off square at both ends. Heat it red hot and apply it again to the same measure ; and it will be found to be considerably longer. Cool it and apply it again, and it will be found to fit the measure as at first.

Rationale. Caloric, being introduced between the particles of iron, separates them a little distance ; though not so far as to bring the iron to a fluid state.

Application. This principle causes the pendulums of clocks and balance wheels of watches, to vary in length according to the varying temperature of the weather ; and consequently to run faster in cold and slower in hot weather.

Prop. 9. *Caloric expands liquids, as well as solids and gases, by entering in and combining with them.*

Illustration. Fill the bulb of a bolthead with cold alcohol ; and on holding it over coals or a candle, the alcohol will expand, and consequently ascend into the neck of the bolthead. A glass tube, luted into the neck of a florence flask, filled with alcohol, will be quite as good.

Rationale. Caloric, being introduced between the particles of alcohol, separates them a little distance from each other, though not far enough to bring the alcohol to the state of vapour.

Application. Thermometers are constructed by confining a liquid (quicksilver or alcohol is generally employed) in a tube with a bulb at the base, containing no air. Degrees are marked against the side of the tube, by which the temperature is indicated as the liquid ascends and descends in the tube. That all thermometers may

be made to accord with each other, the boiling and freezing of pure water, are assumed as starting points. Then the space of the tube between these points is cut into a number of equal divisions, each of which is the measure on every degree above and below, as well as between, those points. Fahrenheit divides this space into 180 parts, Reaumur into 80, De Lisle into 150, the Centigrade into 100. We use Fahrenheit, who begins to count at 32 degrees below freezing, making the boiling point at 212.

Prop. 10. Caloric is transferred through bodies called conductors; and substances differ greatly in their conducting powers.

Illustration. Procure a pipe stem and an iron rod of the same size and length. Make a white wax or bees wax head on one end of each about the size of a musket ball. Put the other end of each close together on burning coals, passing them between two bricks, in order to defend the wax from the direct heat of the coals. Then raise the heat of the coals with a hand bellows, and the head of wax on the iron rod will melt soon; whereas the wax on the pipe stem can scarcely be made to melt. Charcoal is a slow conductor of caloric; which will be well illustrated by burning one side of a small piece of charcoal, while it may be held in the hand by the other side.

Rationale. Caloric is received from the burning coals by both rods. It is then transferred from particle to particle along their whole extent; but it passes with much greater velocity from one particle of iron to the next, than from one particle of the baked clay of the pipe-stem to the next.

Application. An iron stove soon gives off caloric into a room and soon cools ; whereas a brick Russian stove must be heated a long time before it begins to give off caloric into the room, and will not cool in a very long time. Clothes made of wool and silk are slow conductors of caloric : those made of flax conduct caloric rapidly. As stone is a better conductor of caloric than brick, a stone house has its rooms sooner heated in summer and cooled in winter, than a brick house.

Prop. 11. *The same substance is a better conductor of caloric if dark coloured or rough, than if bright, polished or light coloured.*

Illustration. Scratch and blacken with lamp smoke one side of a small tin canister. Fit it to a stand, so that the blackened and polished sides may be readily set at the distance of half an inch from the same side of the bulb of an air thermometer. Now fill the canister with hot water, and present the polished and blackened sides of it alternately to the thermometer several times. The liquid will always sink lowest when the blackened side is presented.

Rationale. As the caloric is transmitted through the rough blackened side with the greatest facility, or rather meets with less obstruction than in passing through the polished side, the air in the bulb of the thermometer receives more caloric from the water in a given time, and is consequently more expanded.

Application. A white earthen teapot will keep the tea hot longer than a black one. A bright tin coffee pot will keep the coffee hot longer than a japanned one. Light coloured clothes will keep

us cooler in hot weather and warmer in cold weather than dark coloured. For our bodies being warmer than the air in cold weather, caloric passes out through our clothes ; but the hot rays of the sun in summer pass through our clothes inwardly.

Prop. 12. *When solids are converted into liquids caloric is absorbed from the adjoining bodies.*

Illustration. Put a table spoon of Epsom salts into a tumbler. Pour twice as much cold water, by measure, upon it. The water and tumbler will become intolerably cold. If ice be dissolved in nitric acid in the same manner, it will give the same result. A freezing mixture may be made as follows : pulverize separately and very finely, one part by weight of sal amoniack and one part of saltpetre. Put these into a tumbler and pour on them three parts by weight of very cold water. Now stir this mixture with a test glass, or a very thin small vial, containing half a teaspoon of cold water. The water in the test glass will soon be frozen.

Rationale. The salts in this mixture, by their action upon each other, and by the aid of the water, are brought to the liquid state. More caloric being required by these substances for their liquid than for their solid state, they absorb it from the nearest substances. Consequently the water in the test glass is deprived of so much of its caloric, as to be reduced to the state of ice.

Application. When snow has commenced thawing by the heat of the sun through the day, it will continue to melt in the evening. During the time it melts in the evening it takes so much

caloric from the atmosphere, as often to render it colder than on a preceding evening while water was freezing into ice.

Prop. 13. *While liquids are converted into vapour or gas, caloric is absorbed from the adjoining bodies.*

Illustration. Wet a piece of thin cotton cloth in ether and lay it on the bulb of the air thermometer, and apply a few drops of ether to the cloth frequently, and the air in the bulb will be condensed. The ether should be quite as warm as the thermometer when applied, to make the experiment a fair one.

Rationale. More caloric being required to convert the ether into vapour, and the thermometer being nearest, it is robbed of part of its caloric.

Application. Inflamed tumors are cooled on this principle by frequently wetting with ether. Rooms are cooled in hot summer days by sprinkling with water; because the water soon passes into vapour and absorbs some of the caloric from the air of the room.

Prop. 14. *When liquids become solids, combined caloric is evolved or pressed out and becomes free.*

Illustration. Prepare liquid muriate of lime as directed under lime. Pour half a spoonfull into a wine glass. Pour in strong sulphuric acid, until a solid is formed. On taking the wine glass between the thumb and finger, the student will find it considerably heated.

Rationale. The sulphuric acid having a superior affinity for the lime, the muriatic acid is forced

out in the state of gas, leaving solid gypsum in the wine glass. The caloric of fluidity being pressed out warms the glass.

Application. When the freezing process commences, and water begins to be converted into ice, or vapour into snow, so much caloric is frequently evolved as very sensibly to diminish the severity of the cold. The heat produced in slaking lime is caused by solidifying water.

Prop. 15. *When vapour or gases become liquids, solids, or more dense vapours or gases, combined caloric of the vapour or gas is evolved or pressed out and becomes free.*

Illustration. Let the flame of burning hydrogen pass into a large dry vial of atmospheric air, and water will be formed which will line the vial with vapour, and great heat will be produced.

Rationale. The burning of the hydrogen is carried on by the union of the oxygen of the atmosphere with the hydrogen; which will be demonstrated under the article hydrogen. When the flame is confined in the vial, water, the product of this combustion, is made manifest. As all the heat, or free caloric, is caused by this process, it follows that the caloric is evolved by the reduction of the gases to the liquid state.

Application. All combustion is explained upon the same principle. For example, successive portions of oxygen coming in contact with heated portions of oil in a lamp or melted tallow of a candle, which are carried up the wick by capillary attraction; the oxygen and oil uniting and forming a more dense gas, a quantity of caloric is pressed out of the oxygen. A continued succession

of such combinations pressing out a continued succession of portions of caloric, from the combined to the free state, produces a continued blaze. All combustibles have an affinity for oxygen, and after combustion are found to be combined with oxygen.

Rooms may be warmed by steam upon this principle. Steam holds a great quantity of caloric in combination, and it is readily condensed by a very little cold water, or by the lower temperature of the metallic tubes in which it is confined. On being condensed, as it passes from the state of vapour to the liquid state, caloric is pressed out from its combined state to a free state, and thus warms the rooms.

Prop. 16. *Free caloric is radiated in all directions from the body from which it is disengaged.*

Illustration. Suspend a heated iron ball by a wire, and hold an air thermometer on all sides of it in succession. It will be found to be equally affected at equal distances.

Rationale. As the thermometer is equally affected on all sides at equal distances, it follows, that its radiation is equal in all directions.

Application. A stove set in or near the centre of a room will afford as much warmth on each of all its sides, as it would on the one exposed side, if set in a side fire-place.

Prop. 17. *Caloric is reflected by hard polished surfaces like light.*

Illustration. Set a bright tin plate on one edge. Set up a board on one edge perpendicular to the middle of the tin plate, so that its nearest edge shall be about two inches from the plate. Sus-

pend a heated ball on one side of the board and set an air thermometer on the other side, so that they may be at equal distances from the board and from the plate. The thermometer will be immediately affected.

Rationale. As the board was interposed between the heated ball and the thermometer, the latter could not be affected directly. Of course the caloric must have been conveyed to the thermometer by reflection upon the tin.

Application. Polished walls of a room, called hard finish, will reflect the caloric radiated from a stove, and thereby cause the air of a room to be warmed much more than papered walls. A room lined with sheet tin might be kept warm with very little fire, on this principle.

PRINCIPLE 3. ELECTRICITY.*

Natural History and general Remarks.

The electric fluid is universally diffused. It presents no phenomena which indicate its presence when in equilibrio. When its equilibrium is disturbed and it is seeking its restoration, it exhibits several interesting properties. Nature thus presents it on a large scale in the terrific form of lightning.

Prop. 1. *The electric fluid is accumulated by friction, and manifests itself by attraction and repulsion.*

* Electricity was not considered as belonging to the department of Chemistry by Lavoisier, Henry, Accum and others, who wrote their systems as early as the year 1810, and previous. As some important decompositions are now effected by the power of electricity, a few of its principles ought to be illustrated; though its most important phenomena are referrible to natural philosophy.

Illustration. Lay a half sheet of paper upon a warm smooth board or table. Rub the paper smartly with a large thick piece of India rubber, as if rubbing out pencil marks, about a dozen strokes. Now lift up one end of the paper and let it fall back on the board, and it will go down with force, being moved by electrical attraction. It will also adhere to the side of a ceiling. Hold light down suspended by fine threads near the paper, and it will be attracted and repelled alternately. Rub a glass cylinder, a stick of sealing wax, a piece of rosin, amber, or gum-copal, with a dry silk handkerchief, and it will attract and repel alternately, suspended pieces of cork, feathers, tow, thread, &c. The substance should be warmed, and the experiment should be made when the atmosphere is dry and the wind northerly.

Rationale. The electric fluid being accumulated by friction, it makes an effort to pass off to restore its equilibrium; in doing which it attracts those bodies. After being a short time in contact, electrified bodies repel each other. See Webster's Philosophy, head Electricity.

Application. In cold dry weather, when the atmosphere is always highly charged with the electric fluid, our clothes often exhibit analogous appearances when we put them off or on in a cold room; which are to be explained on the same principle.

Remark. The electric fluid is accumulated more expeditiously by the aid of an amalgam, as follows: Melt one part of tin and two parts of zinc, and stir them well together in the ladle. Heat six parts of mercury so that water will hiss when poured upon it. Put the three metals into

a warm iron mortar, and rub them to a powder with a pestle. The amalgam will now be prepared for use. The best way of using it is, to rub cold tallow upon a piece of soft leather, and then spread the amalgam upon the tallow, pressing it on hard with a wide knife-blade.

Prop. 2. The electric fluid is accumulated by the action of diluted acids upon pairs of metallic plates, and tends to restore its equilibrium in the direction of the metal which has the strongest attraction for oxygen.

Illustration. Make a trough of baked mahogany, and divide it into half inch portions by metallic partitions. Each of these partitions to be made of a plate of zinc and copper soldered together at the edges, and set in with the same metals the same way. Fill these portions or divisions with a liquid consisting of one part of sulphuric acid, one part of nitric acid, and sixty parts of water. Now fit in a wire at each end of the trough, by coiling one end spirally so that it will spring strongly against the two extreme metallic plates, when inserted into the end cells or divisions. Bring the other ends of the wires almost together, and sparks will pass from one to the other.

Rationale. All the zinc plates being in one direction and the copper plates in the other, and zinc having a stronger attraction for oxygen than copper, the electric fluid tends to restore its equilibrium in the direction of the zinc side of the plates. When the conducting wires are brought together, the electric fluid passes from the zinc (or positive) side over to the copper (or negative) side.

Application. If an animal, but recently dead, be placed in the circle with a proper application of the wires to a nerve and a muscle, the animal will exhibit signs of life. Any metal, even platina, if placed in the circle will burn like tinder. This application of electricity is called GALVANISM.

Prop. 3. *Compounds, of which one of the constituents is oxygen, may be decomposed if placed in the galvanic circle—the oxygen always going to the positive side or pole.*

Illustration. Place the two ends of the wire conductors in the opposite sides of a wine glass of water, and the oxygen will go to the positive pole, and if iron, will unite with it, while the hydrogen will rise up in bubbles from the negative pole. Solutions of salts are decomposed; the acids going to the positive, and the bases to the negative poles. Acids are decomposed; the oxygen going to the positive pole and the acidifiable bases to the negative.

Rationale. The same as in the last proposition.

Application. By this mode of applying electricity, potash, soda, lime, and many other bodies may be decomposed, which resist the most powerful chemical agents.

PRINCIPLE 4. LIGHT.

Natural History and general Remarks.

Light is chiefly derived from the sun, in the solar system. This is called solar light or celestial light. It is also derived from terrestrial objects; as from combustion, friction, chemical attraction,

&c. This is called terrestrial light. It is generally accompanied by caloric.

Every ray of common light contains in itself seven different kinds. These may be best separated by a triangular glass prism; but the same operation may be performed with a tumbler of water. Such experiments, however, belong to the department of natural philosophy. The seven kinds of light differ in two remarkable characteristics. They are of different colours and of different degrees of refrangibility. They are red, orange, yellow, green, blue, indigo, and violet. The red is least refrangible, the violet most; and the intermediates vary in their degrees of refrangibility according to this order of succession. The different colouring of bodies depends on the different kinds of light which they reflect to the eye. White bodies reflect all kinds of light—black reflect none.

Prop. 1. The different kinds of light are reflected according to the arrangement of the constituent atoms of bodies reflecting them; not according to the nature of those atoms.

Illustration. Prepare the following solutions as here directed: 1. Sugar of lead dissolved, 1 to 50 of water by weight—2. Pearlash, 1 to 4 of water—3. Corrosive sublimate, 1 to 30 of water—4. Copperas, 1 to 6 of water—5. Sulphuric acid, 1 to 12 of water—6. Verdigris, 1 to 100 of water—7. Strong liquid ammonia—8. Tincture of red cabbage—9. Tincture of galls—10. Prussiate of potash—11. Nitrate of mercury, made of 1 of mercury to 4 of nitric acid, to which is added twice as much water.

By mixing these liquids we make,

Red—One of 5 with one of 8.

Orange—Four of 3 with one of 2.

Limpid with one of 5.

Yellow—Four of 11 with one of 2.

Green—Three of 8 with one of 2.

Ruby red with one of 5.

Blue—Three of 6 with one of 7.

Limpid with one of 5.

Indigo—One of 4 with one of 10.

Violet—Add the red to the indigo.

White—Mix three of 1 with one of 2.

Black—Three of 9 with one of 4.

Limpid with one of 5.

Rationale. These liquids either reflect different colours before they are mixed, from those which they reflect afterwards, or reflect no colours as some of them are limpid. It follows as a necessary conclusion, that colouring is not inherent in matter, but depends on the peculiar arrangement of the constituent atoms. For if inherent in matter the same matter would always present the same colours.

Application. As colours are changed by the various applications of the laws of chemical affinity, dyers, limners, &c. ought to be well acquainted with these laws. Mordants sometimes only fix a colour by their affinity for the stuff and for the colouring matter. In other cases they effect a total decomposition of the colouring matter, and thereby produce new colours.

Prop. 2. *Light decomposes many substances by its direct action upon their elementary constituents.*

Illustration. Put oxymuriatic acid gas (chlorine gas) into a vial, cork it tight and set it in a window exposed to the rays of the sun. In a few

days examine it, and it will be found to consist of muriatic acid and oxygen.

Fill a bell-glass or large tumbler loosely with mint, hyssop, savory, or some other leaves and herbage, collected in the morning before sun-rise. Fill the same up with water, and invert it in a plate filled with water. This operation is best performed in a cistern or tub of water. Set it in a window, exposed to the rays of the sun. Bubbles will soon appear on all parts of the leaves, which, on shaking the whole a little, will rise to the upper part of the vessel. Towards evening immerse it in a tub of water or cistern, and draw out the leaves through water. Now experiment upon this gas, as in other cases, and it will be found to be pure oxygen. Perhaps the best method will be to fill a small wide mouthed vial with it, and test it by dipping an extinguished candle into it; which will be lighted by the heat of the sparks on the wick.

Rationale. In this case we can merely refer to facts, without being able to assign their cause. Light eliminates oxygen from its compounds in numerous cases. In the case of the chlorine or oxymuriatic acid, the additional portion of oxygen, which converts muriatic acid into the oxymuriatic, is disengaged, leaving the muriatic.

Application. The green colour of vegetables is produced by the action of light. For potatoe vines growing in a dark cellar, and other vegetables excluded from light, are not green. A prisoner long confined in a dungeon loses his usual colour and becomes of a peculiar white, unlike those equally confined where light is admitted.

Prop. 3. *Light is radiated from many substances which seem not to belong to the class of luminous bodies ; which light is denominated phosphorescence.*

Illustration. Rub two pieces of white quartz slightly together in the dark, and they will become luminous.

Rationale. In this case nothing like the scintillations of flint and steel is the cause of the luminous appearance. Neither is there any phosphorus in combination with common quartz. This and some other minerals either absorb light and give it off when rubbed, or possess a peculiar property, which cannot be referred to any classification of the phenomena of light.

Application. Some bodies absorb and give off light, as rotten wood, putrid fish, some artificial preparations, &c. Snow absorbs light by day, which it gives off at night ; which may be demonstrated by opening a window in a dark night and the room will be actually illuminated considerably.

CLASS II. ACIDIFYING SUBSTANCES.

PRINCIPLE 1. OXYGEN.

Natural History and general Remarks.

Oxygen is very generally diffused, though not so universally as caloric, electricity and light. It is one of the constituents of the atmosphere; composing about 21 per cent of it. It is the only souring or acidifying principle used by nature; and probably so in all artificial preparations. It is found in nature in the solid, liquid and gaseous state; but when pure it is always in the gaseous state. It is combined with most of the metals in a solid state forming what are called oxids of metals, and also acids in a few cases. As the ores called oxid of iron, oxid of manganese, &c. chromic acid in the chromate of iron, &c. It is combined with hydrogen in the liquid state, forming water, and with carbon in the gaseous state, forming carbonic acid gas. The same acid is solid in a tripple compound, as in the common marble, which consists of carbonic acid and lime. In the state of combination, oxygen is found solid in primitive, transition and secondary rocks. Therefore, the earth, the ocean and the air abound in it.

Proposition 1. Oxygen is found in great abundance in combination with metals, from which it may be disengaged by caloric in the state of gas.

Illustration. Pulverize the black oxid of manganese in an iron mortar. Fill about ten inches of a gun-barrel with it. Put the end containing the manganese into a fire. A furnace is best; but if the door of a common close stove be taken off and set bottom up, so that the gun-barrel may lie

in the notch or hole in the bottom of the door, with the lower end in the fire, and the mouth elevated, it will heat to good advantage. A leaden tube must be fitted to the mouth of the gun-barrel, which leads to the cistern, passing the end under the funnel in the moveable shelf. Over this the bell-glass or other receiver must stand, filled with water. The leaden tube must be fitted to the mouth of the gun-barrel. No luting will be necessary. Merely wind a little wet flax or tow around the pipe and ring it in forcibly. Then suck at the end of the leaden tube, so as to exhaust considerable of the air, and placing the tongue over the end, wait a moment to see whether the tongue will be released. If not, all is tight. Be sure to have some part of the tube considerably higher than the water of the cistern, by bending it arching upwards. Otherwise water may get into the gun-barrel and cause an explosion with steam.

The apparatus being thus prepared, raise the heat with charcoal or good dry hard wood, and keep the gun-barrel at a moderate red heat. At first collect the gas that comes over in a small open-mouth vial; the opodeldoc vials will do. Frequently try it by dipping the hot wick of an extinguished candle into it. When the candle is lighted in it by the sparks and heat of the wick, begin to save it for use. About one gallon of the gas may be collected from ten inches of the Bennington manganese. But there is great difference in manganese. Some contains a great quantity of carbonate of iron, and carbonic acid will come over sometime before the oxygen appears.

Red lead, being oxygen and lead, is quite as good as the manganese; but it is very difficult to

clear out the gun-barrel after the process is ended. Whereas manganese is easily emptied out.

Rationale. Oxygen is combined with manganese in a solid state. By applying heat, the caloric enters into combination with the metal and the oxygen. The manganese will not ever become fused without more than ten thousand degrees of heat, but the oxygen will be disengaged and converted into gas at about one thousand degrees. It then comes over and assumes the temperature of the atmosphere.

Application. We are taught by this experiment, that the pure respirable part of the air we breathe may be a solid in combination, and be brought back to air again by heat.

Prop. 2. *Some acids hold their highest proportions of oxygen by so feeble a tenure, that though combined with a base in the state of a salt, they will give it off in the state of gas, when but slightly heated.*

Illustration. If saltpetre is coarsely pulverized and put into a gun-barrel, and conducted according to the directions for manganese, excepting that the barrel must hardly be heated to redness, the saltpetre will melt and boil, and soon after oxygen gas will come over.

Rationale. Saltpetre consists of nitric acid and potash. The nitric acid parts with its highest portions of oxygen by being heated, and the salt is reduced to the nitrite of potash. This acid will be fully described under Nitrogen.

Application. The facility with which oxygen is obtained from saltpetre, is the property on which its use in the manufacture of gun-powder depends.

There is another substance, called oxymuriate of potash, from which pure oxygen may be obtained on the same principle with much less heat, and is very explosive.

Prop. 3. *Oxygen is the only supporter of combustion in the atmosphere.*

Illustration. Having obtained some nitrogen gas (which is the other constituent of the atmosphere) by the process hereafter to be described, fill a small glass cylinder, or wide mouth vial with it, dip a burning candle into it, and the candle will be extinguished. Now fill the same vessel about three fourths full of nitrogen, and fill up the remainder with oxygen. Let the two gases stand a few minutes to mix according to those equilibrium laws which govern their union. Let down into it a short piece of a burning candle by a wire, and it will burn as in common atmospheric air.

Rationale. As the candle would not burn in nitrogen and now does burn after the introduction of oxygen, it is manifest that it is the oxygen which supports the combustion.

Application. When much of the oxygen has been consumed by the breathing of a crowded assembly in a close room, candles do not burn in the room with the same brilliancy.

Prop. 4. *Oxygen promotes combustion vehemently when pure.*

Illustration. Fill a glass cylinder with oxygen, and let down a short piece of a burning candle into it by a wire, and it will burn vehemently.

Rationale. Oxygen being mixed with nitrogen in the atmosphere, and nitrogen not being a sup-

porter of combustion, the strong action of the oxygen as a supporter of combustion is restrained. But when it is divested of the nitrogen, it acts with all its force.

Application. The necessity for having oxygen diluted with nitrogen is manifest; for if the atmosphere were pure oxygen, all combustible substances, when once inflamed, would burn without controul, to the destruction of all the living beings inhabiting the earth.

Prop. 5. *Some metals will burn vehemently; after being inflamed, in pure oxygen.*

Illustration. Coil up a piece of fine iron wire, sometimes called harpsicord wire, which is about the size of sewing thread. It will take the most suitable form by winding it spirally and closely around a pipe stem. Let the coil be three or four inches long, with the upper end fitted into a cork, which suits the mouth of an 8 ounce vial. Fill the vial nearly with oxygen, leaving only water enough in it to cover the bottom an inch thick, to defend it from being broken with the globules of hot oxyd of iron which will fall upon it. Set the vial on the table, stopped with another cork. Now tie a small knot of silk thread on the lower end of the coil, hold a piece of brimstone in the candle till it melts a small spot, blow out the blaze of brimstone and dip in the knot of thread. Be sure that the thread and melted brimstone that adheres to it, all do not exceed in size a large pin-head. All being ready, pull out the cork from the vial, hold the thumb over the mouth, and let an assistant steady the vial. Now light the brimstone match and put the coil of wire quickly into the vial, fitting in the cork to which it is attached.

Lift up the vial by the neck, that all the class may see the wire burn ; which will send off brilliant sparks and make a beautiful exhibition.

If a wire, which is about twice as large as the coil, be flattened with a hammer, and so fitted into the cork as to extend down through the centre of the coil, and it be set on fire at the same time, and in the same manner with the coil, it will present a very curious appearance. The central wire will burn with a large globular flame, while a smaller globular flame will perform revolutions around it, resembling the motion of a planet around the sun. If a still finer wire is coiled around the first coil and ignited, a moon will be seen revolving around the planet, while the planet revolves around the sun.

Rationale. Same as in Prop. 4.

Application. From this experiment it appears, that if the oxygen of the atmosphere were not diluted or reduced in power by nitrogen, even iron would not resist combustion. Our iron stoves would burn with the fuel put into them; the smith's hammer and anvil would blaze like tinder.

Prop. 6. *Oxygen is the acidifying or souring principle.*

Illustration. Fill an opodeldoc vial with oxygen, leaving half a spoon-full of pure water in the bottom. Put a piece of phosphorus, of the size of a pea, into a mustard spoon or a strip of tin bent in the same form. Suspend it from the end of a large piece of wire or iron rod, forming a convenient handle to move it with. All being ready, pull the cork out of the vial and hold the thumb

upon it; let an assistant steady the vial and hold a candle with the blaze very near the mouth of it. Now take off the thumb, touch the phosphorus to the candle, and in the same instant let it down into the vial of oxygen. It will burn most brilliantly and probably crack the vial. A white flocculent substance will line the vial. Whether the vial breaks or not, rinse off this white substance in the water in the bottom of the vial. Now pass this liquid about in wine glasses, and the class will perceive that something has given acidity to the phosphorus.

Rationale. As nothing but phosphorus and oxygen were in the vial, with the little water in the bottom of it, the acidity of the water must have been caused by the union of the oxygen and phosphorus.

Application. This applies to all acids, as will be shown under each.

NOMENCLATURE.

Oxygen enters into combination with acidifiable substances, in several definite proportions, which requires a peculiar nomenclature. When combined in the lower proportions, they are called *oxids*, or *oxides*, in the higher proportions they are called *acids*. The proportions of oxygen in the oxids are expressed by the Greek numerals. As *protoxid*, *deutoxid*, *tritoxid*, and *peroxid*. For example, the metal called manganese is said to combine with four definite proportions of oxygen, forming the *protoxid* of *manganese*, the *deutoxid* of *manganese*, the *tritoxid* of *manganese*, and the *peroxid* of *manganese*. Some metals do not

unite with oxygen in more than one proportion, some with two, some with three, none more than four.

The proportions of oxygen in acids is expressed by the terminations *ous* and *ic*. As *sulphurous* and *sulphuric* acid. When acids contain more than two proportions of oxygen, the term *hypo* is prefixed to the name next below which it stands. As *hypo-sulphuric* acid, implies an acid composed of sulphur and the next proportion of oxygen below that contained in sulphuric acid. *Hypo-sulphurous* acid would express the acid which contained a definite proportion of oxygen, next below that contained in sulphurous acid. If the acid combines with higher proportions of oxygen than that expressed by the termination *ic*, they are expressed by *oxygenated* and by *hyper*. As *muriatic* acid, when combined with one higher proportion, is called *oxygenated* muriatic acid—when two proportions, *hyper-oxygenated* muriatic acid. *Oxygenated* is usually abbreviated, so as to form *oxy-muriatic*.

Some oxids, which are in the state of gas, are expressed by substituting the adjectives in *ous* and *ic* for the Greek numerals. Thus we say *nitrous oxid* and *nitric oxid*.

PRINCIPLE 2. CHLORINE.

Natural History and general Remarks.

Chlorine is an artificial substance. If simple, it exists in nature in a state of combination with hydrogen, forming muriatic acid. Whether simple or compound, has been a subject of much discussion; though the question is immaterial in respect

to its use in the arts. The question ought to be decided by bringing chlorine and ammonia together in the state of perfectly dry gases. According to Murray, muriate of ammonia and some water are always produced. If so, chlorine must be a compound of muriatic acid and oxygen. Its oxygen goes to a part of the hydrogen of the ammonia and forms water, while the muriatic acid unites with the remainder of undecomposed ammonia. But Davy says, these gases may be so well dried, that they may be united without producing any water. Students who are desirous to examine the arguments on both sides, may read Cooper's note to Chlorine, in his American edition of Thompson's Chemistry.

Muriatic acid is the substance in which we are to consider the natural history of chlorine; for chlorine is obtained from it, either by adding oxygen to it, or by divesting it of its hydrogen. Muriatic acid being one of the constituents of common salt, it is as extensive as the waters of the ocean, the waters of salt springs, and the mines of solid salt.

It may be proper to add, that some of the advocates for the chloridic theory, consider common table salt as analagous to the oxids. That it is the *chlorid of sodium*, and not a salt.

Prop. 1. *Chlorine is obtained in the state of gas from common table salt by the aid of the oxid of a metal, and a strong acid.*

Illustration. Put into a half pint retort a pulverized mixture, well rubbed together, consisting of a tea spoon-full of manganese with twice as much table salt. Then pour into the retort about two tea spoons of sulphuric acid, with half as

much water. Apply the heat of a candle to the retort, and the chlorine gas will come over. It ought not to be collected in the cistern; for the cistern water will give off a disagreeable odour for many days afterwards. Invert the receivers in a large wash-bowl, and let the water be warm to prevent the absorption of the gas.

As this gas is destructive to the lungs, very small quantities should be used in the laboratory. Opodeldoc vials, (used as receivers) should be prepared, filled with water, and inverted in the bowl, before the process commences. Just vials enough should be filled for the proposed experiments; then the retort should be instantly carried out of the room. The vials should be corked closely, and the water immediately thrown out.

Rationale. This process is explained on two very different hypotheses. Lavoisier, Berzelius, Murray and others, say that the muriatic acid, being disengaged from the soda, and oxygen from the manganese, the muriatic acid unites with a definite proportion of oxygen, and forms the oxy-muriatic acid; that is, this gas consists of muriatic acid with an additional proportion of oxygen. Davy and others say, that the oxygen disengaged from the manganese unites with a portion of hydrogen, and forms water; which hydrogen, they say, combined with chlorine, forms the muriatic acid. The chlorine being thus divested of the hydrogen, which held it in the state of muriatic acid, comes over a pure, simple, yellowish green, suffocating gas.

Application. On this principle, and by a more economical use of the same substances, the same gas is obtained and combined with water, to form

the bleaching liquor. But the gas is often disengaged in large quantities from the water, when its temperature is a little raised; which is very suffocating and injurious to the health of workmen. To remedy this inconvenience, the chlorine is united to lime, forming an oxymuriate or chlorid of lime. See this subject again under lime.

Prop. 2. *Chlorine gas feebly supports combustion, and inflames some substances spontaneously.*

Illustration. Fill an opodeldoc vial with the gas. Immerse a short piece of a burning candle in it, held upright by a wire. It will burn a short time with a deep coloured flame and much dense smoke.

Fill another, and immerse in it a small piece of phosphorus, in a mustard spoon. It will take fire and burn spontaneously.

Fill another, and immerse in it gold, silver and copper leaf, they will soon take fire spontaneously. Brass or copper wire will burn in this gas, if immersed in a vial of it when heated to redness in a candle. For all these experiments the gas must be just made and kept warm.

Rationale. Those who consider chlorine as muriatic acid with an additional portion of oxygen, say, the candle burns with the additional portion of oxygen, which the muriatic acid readily parts with. And that the action of the acid, combined with the excess of oxygen, causes the spontaneous combustion. Those who consider chlorine as a simple substance, say, these cases of combustion are evidence that it is entitled to a place in this class with oxygen; and that it supports combustion of itself independently of oxygen.

Application. The facility with which chlorine inflames combustible substances, renders salts made with it very suitable for fire-works. Oxy-muriate of potash readily inflames many combustible substances by mere compression in contact with them.

Prop. 3. *Chlorine extinguishes vegetable colours, if the substances to be operated upon are moistened, or if the chlorine is in a liquid state.*

Illustration. Obtain chlorine in the liquid state, as follows: Fill a strong quart decanter one third full of water. Put into it a pulverized mixture, consisting of half a gill by measure of red lead and a gill of common table salt, well rubbed together. After shaking it up, put into the decanter two thirds of a wine glass of sulphuric acid. Put in a ground glass stopper loosely, and shake the decanter half a minute. The atmospheric air and some gas will escape. Now press in the glass stopper perfectly tight and plunge the decanter into a tub or cistern of cold water, just keeping the mouth above water. Agitate it as much as may be done under water, about once each minute, for fifteen minutes. Now take it out and let the excess of red lead and salt settle. The sulphuric acid must never be in excess. The liquid will now become yellowish-green, and will be tolerably pure; though it will contain a little muriatic acid. Pour a little into a wine glass, and with it wash out writing from paper, and extinguish the colours from calico.

Fill an 8 ounce vial with the chlorine gas. Wet or dampen one end of a piece of calico, and insert it into the vial by the side of the cork, leaving the dry end out. The wet end in the vial will soon become faded.

Rationale. The chlorine becomes muriatic acid by parting with its oxygen. And it has been found, by the use of sulphurous acid and of some other compounds, that oxygen thus imparted will extinguish vegetable colours.

Application. The liquid chlorine obtained in this way may be kept in vials in a dark cool place, and used for taking spots out of linen, &c. It has been employed for fraudulent purposes, to obliterate written instruments so as to write something different in the same place.

This may be readily detected by prussiate of potash. For wherever it has been applied, the place will become green on the application of a solution of prussiate of potash.

Prop. 4. *Muriatic acid,* from which chlorine is made, is obtained from common table salt by elective affinity.*

Illustration. Fill two or three vials or small cylinders with mercury and invert them in the trough. Lute very firmly a pipe bowl to the mouth of a tubulated half pint retort, with half an inch of the stem remaining, which must point upwards. Having previously dried some fine salt on an earthen plate, put into the retort, through the tubulature, a wine glass full of the salt. Place the retort in a fixed steady position, with the beak in the trough, so as to immerse the pipe bowl and stem under the mercury; but do not place any of the receivers in a situation to collect the gas yet. All being ready, now pour gradually into the re-

* Muriatic acid was supposed to consist of an unknown base combined with oxygen, until the chloridic theory was introduced. Many able chemists still believe in the old hypothesis; and consider the new one as an unnecessary anomaly.

tort, through the tubulature, as much strong sulphuric acid as will be sufficient to moisten, or rather wet, the salt. Considerable gas will be given off immediately and pass out at the tubulature; but not more than is necessary for driving out the air and vapour which were in the retort. Put in the stopper, and let the gas waste a few seconds through the pipe stem. Now move one of the receivers to receive the gas, setting it down so as to bring the pipe stem a little way into the mouth of the receiver, whether a vial or glass cylinder; because the gas will not ascend into it if merely brought under it, as the practice is when receivers are filled with water. Two or three small receivers will now be soon filled with pure muriatic acid gas. But if a sufficient quantity does not come over, apply a candle to the retort. This gas may be collected for ordinary experiments, without a mercurial trough. As it is heavier than atmospheric air, set an 8 ounce vial on the table inclined a little to one side, and insert the neck of the retort, extending its beak to the bottom of the vial. The gas will soon force out the air and fill the vial. A goose quill with the feathered end dipped in liquid ammonia may be used to determine when the vial is full. For the ammonia will form a cloud about the mouth of the vial when it is filled and runs over. Several vials may be filled and corked tight; each to be used for a separate experiment.

Rationale. Common salt consists of muriatic acid and soda. The soda elects the sulphuric acid, and excludes the muriatic; forming Glauber's salts, which remain in the retort.

Application. On this principle the muriatic

acid, called spirits of salt, which is used by artists, may be obtained. For if the gas be passed into a receiver containing water, the water will absorb it and the common liquid, muriatic acid of the shops, will be formed.

Prop. 5. *Muriatic acid is strongly absorbed by water or ice.*

Illustration. When the muriatic acid has almost ceased to come over by the last described process, take up the retort, pull off the pipe bowl and set the mouth in water, holding the neck in a vertical position. The water will ascend in the neck of the retort, and at length fill it.

Cut a piece of ice of a suitable form for entering the mouth of one of the vials of gas, and pass it in through the mercury. It will become liquid, and mercury will ascend and fill the vial. Invert one of the vials of gas and place its mouth in a bowl of water. The water will ascend and fill it.

Rationale. Water absorbs muriatic acid gas so powerfully, that it combines with it immediately. Its volume being thus reduced to almost nothing, a vacuum is formed into which the water or mercury rushes by force of atmospheric pressure.

Application. The strong attraction existing between muriatic acid and water, still exists when the acid is combined with soda in the state of salt. This accounts for the salt's forcing ice into the liquid state when they are used together for a freezing mixture—also, when salt is used for thawing out a pump, &c.

Prop. 6. *Muriatic acid gas extinguishes flame, first giving it a green tinge.*

Illustration. Let down a short piece of candle slowly into an opodeldoc vial of the gas. As the candle enters the gas, a green ring will encircle the base of the flame. On immersing it a little farther, it will be extinguished.

Rationale. Though muriatic acid gas extinguishes flame, it gives a green tinge to it after mixing with the nearest portion of atmospheric air.

Application. This experiment seems to shew, that the muriatic acid possesses some faint vestige of that property of the chlorine which enables it to support combustion.

Prop. 7. *Muriatic acid may be arrested in water standing over common salt, at the moment of its escape; forming the liquid spirits of salt, or the muriatic acid of the shops.*

Illustration. Having heated common table salt in a crucible to a moderate red heat and let it cool, put an ounce into a tubulated pint retort. Pour through the tubulature, upon the salt, the same weight of diluted sulphuric acid, consisting of equal measures of the best sulphuric acid of the shops, and water, after they had been mixed and cooled. Then distil over the liquid muriatic acid. This may be easily done, by fitting the neck of the retort to a receiver, immersed in cold water or surrounded with ice or snow, and applying a very moderate heat to the retort. A sand bath, or coals in a lead pot, will give a due degree of heat.

Rationale. The muriatic acid is disengaged from the soda, as when we obtain it in the state of gas; but it is arrested in the water which is mixed with the sulphuric acid. On distillation the muriatic acid and water come over in vapour, and are

condensed into a liquid, leaving the sulphate of soda in the retort.

Application. By this method a physician or an artist may obtain the acid, whose purity he is acquainted with, by very little labour or expense. And in the same experiment we illustrate the doctrine of elective affinity, forcible attraction, and the motion of caloric in evaporation and condensation.

PRINCIPLE 3. FLUORINE.

Natural History and general Remarks.

Fluoric acid is chiefly found in combination with lime, constituting the fluor spar. From its analogy to other acids, it was supposed to have an acidifiable base, which is combined with oxygen. This base was never discovered. The acid so nearly resembles the muriatic acid, that it seemed necessary to suppose, that it consisted of hydrogen and a simple substance analogous to chlorine. Therefore to accommodate the chloridic theory, a fluorine is assumed, with little or no evidence.

Fluoric acid has been found in topaz, and in a few other minerals; but it is always obtained from fluor spar when used in the arts.

Prop. 1. *Fluoric acid dissolves flint and glass. It is found constituting an essential part of fluor spar, from which it may be obtained in the state of gas, by elective affinity.*

Illustration. Put into the etching box a tea spoon full of coarsely pulverized fluor spar, and set the box into a dripping pan of coals placed on bricks upon the table. Pour in strong sulphuric acid, just sufficient to moisten or moderately wet

the fluor spar. Fluoric acid will immediately rise up out of the cup, which may be known by its attracting so much vapour from the air as to exhibit the appearance of common steam. As soon as it begins to appear, which will be in a few seconds, lay over the cup a piece of common window glass, large enough to cover its mouth, which had been previously waxed and written upon. Let an assistant instantly apply snow, ice, or cold water, to the upper side of the glass, in order to keep it so cool as to prevent the wax which is on the under side from melting. Take off the glass in ten seconds and apply another, and so on. Two or three may be applied before the fluor spar and sulphuric acid are renewed. The writing made in the wax will appear beautifully etched upon the glass on scraping off the wax.

The best method of preparing the glass, is to warm, or rather heat moderately, the face of a smoothing iron or piece of polished marble, so that white wax or very fine beeswax will melt on being applied to it. Lay the glass flat upon the melted wax, and on sliding it off, it will be very evenly waxed. A dozen pieces or more may be prepared in succession. The writing may be made with the end of a hard stick, nail, &c. Care must be taken to lay the glass perfectly bare throughout all the strokes, or there will be interruptions in the etching.

Rationale. The lime elects the sulphuric acid, and excludes the fluoric in the state of gas. This gas has a strong affinity for silex, with which it unites and forms a fluo-silicious gas, leaving the etched channels.

Application. Any devise, name, stanza, &c.

may be etched in this way, not only upon glass, but upon any silicious substance. Common flint, common chalcedony, the carnelion, &c. may be engraved in the same manner.

PRINCIPLE 4. IODINE.

Natural History and general Remarks.

Iodine is obtained from barilla (the coarse impure soda,) or from the sea weeds from which the barilla is obtained. Whether it exists as a ready formed simple substance in the sea weed, or whether it is a compound, produced in the process of obtaining it, is not known. It possesses several properties in common with chlorine. Being always in connexion with muriatic acid, it may be a compound of that substance, somewhat analogous to the combination of muriatic acid with oxygen, in forming chlorine. But as it has not yet been decomposed, it is treated as a simple substance. To call a substance simple, merely because it has not been decomposed, is a rule adopted when it will aid in the cause of a favorite hypothesis only. Muriatic acid and fluoric acid were always considered as compound from mere analogy, when neither of them was supposed to have been decomposed. And it is not probable that any one would have even suspected iodine to be a simple substance, had it not been necessary for the support of the chloridic theory.*

* We have a remarkable specimen of curious reasoning in support of a favorite hypothesis in some of the writings of Sir Humphrey Davy. He says, that according to the sound logic of chemistry, chlorine and iodine must be considered as simple substances, because they have not been decomposed. But in support of another favourite hypothesis (that all earths have metallic bases, and must be classed with metals,) he assumes, from analogy merely, that alumine, glycine, zincon and

Iodine at the common temperature, is in the state of solid scales, of a steel-grey colour. In this it differs from chlorine, which is in a state of gas when pure.

Prop. 1. *Iodine becomes a purple gas on raising the temperature a little.*

Illustration. Put a few scales of iodine into a test glass or small vial. Cork the vial quickly to prevent much air from coming in contact with it. Warm the vial over coals, until the scales are converted into a purple gas. Immerse the vial in cold water or snow, and the purple gas will return to solid scales.

Rationale. At the common temperature this substance is a solid; but by giving it more caloric it becomes a gas.

Application. This experiment shows that the same substance may change its colour by merely receiving an additional portion of caloric.

Prop. 2. *Iodine gives different colours to different substances.*

Illustration. Put a few scales of iodine into a tea spoon of alcohol in a wine glass, it will give a reddish purple colour. Put a few scales into a solution of starch, and it will give a dark purple colour. Put a few scales on a bright silver dollar, and it will give an iridescent hue. Rub a few scales between the fingers, and it will give to the skin a dirty yellow colour.

Rationale. We can only refer these results to the general proposition under light; that different

yttria, are compounds of different metals and oxygen; though they have never been decomposed, nor a shadow of evidence of their compound nature has hitherto been deduced from experiment.

colours depend on the different arrangement of constituent atoms.

Application. The above solution in alcohol is used by physicians in the scrofula. The other combinations are subjects of curiosity only. See New-York Medical and Physicial Journal, p. 263, 519.

NOMENCLATURE.

A peculiar nomenclature has been introduced for *chlorine* and *iodine*, when in combination with other substances. Considering them as analogous to oxygen, their nomenclature is also analogous. If uncombined chlorine or iodine is united with a metallic base, the compound is called a *chlorid* or *iodid* of that metal. When they are supposed to be united with oxygen, the termination is in *ic*, as in other compounds of oxygen where an acid is formed, &c. A comparative view of the nomenclature of those who do, and of those who do not, believe these to be simple substances, will sufficiently illustrate this nomenclature. Chlorine and iodine are oxymuriatic acid and oxiodiatic acid. Hydrochloric acid and hydriodic acid are muriatic acid and iodiatic acid. Chloric acid and iodic acid are hyperoxymuriatic acid, and hyperoxiodiatic acid. Their salts are expressed by terminating the names of their acids in *ate* and *ite*, as will be explained hereafter, in regard to salts in general.

CLASS III. OXIDABLE SUBSTANCES, NOT METALLIC.

PRINCIPLE 1. HYDROGEN.

Natural History and general Remarks.

As water is a compound of hydrogen and oxygen, it is as extensively diffused as water. Water of crystallization forms a part of crystals, constituting rocks of all formations, from the oldest to the most recent. Hydrogen is one of the essential constituents of all animal and vegetable matter. It is also found pure. Whatever decomposes water by attracting and uniting with its oxygen, disengages the hydrogen in an uncombined state. It appears also, as a production of nature, in the state of several compound gases; such as the sulphuretted hydrogen, a very nauseous scented gas, the carburetted hydrogen, which issues from decaying vegetables and coal mines, &c. It issues from decaying animal matter in combination with nitrogen, forming ammonia.

Prop. 1. Hydrogen and oxygen being the combined constituents forming water, if the oxygen of the water is united to a metal by elective affinity, the hydrogen will come over in the state of gas.

Illustration. Put half a gill of water into a pint retort, to be decomposed. Put into the water a table spoonfull of iron filings, or half as much zinc, hydrogen would come over, after a long time, in small quantities. As this operation would require several months, put in diluted sulphuric acid, consisting of a wine glass one third full of sulphuric acid, filled up with water, to hasten the

process. Hydrogen gas will come over immediately and with great rapidity. If a smaller proportion of sulphuric acid be put in, the gas will come over slower and continue longer. It may be received over water in bell-glasses, tumblers, gas-holders, decanters, &c.

The sulphuric acid may be dispensed with, if the water be converted into steam and pass over hot iron. This may be performed by passing an open gun-barrel across a furnace and heating it red hot ; while water is boiling at the lower end in a tin cup, box, or glass retort with a neck fitted to the gun-barrel. Iron filings or wire may be put into the gun-barrel ; but the heated inner surface of a new barrel will decompose the water, without the filings or wire, for a short time.

Rationale. The oxygen of water has a stronger affinity for iron than for hydrogen, consequently elects the iron and excludes the hydrogen. And though the hydrogen is in a liquid state when combined with oxygen, it takes so much caloric when in a free state as to become a gas. It is not known how the sulphuric acid acts upon the iron or upon the water in so rapidly hastening the process of decomposition. We can say, that in a manner not yet explained, it excites a strong predisposition in the iron and oxygen to unite. As muriatic acid produces the same effect, it cannot be ascribed to any decomposition of the acid, as suggested by Dr. Cox ; for muriatic acid cannot be decomposed—at least so as to separate oxygen from a base.

Application. Earthquakes are probably caused by hydrogen in some instances ; but more frequently by sulphuretted hydrogen. Iron and wa-

ter are in contact in the earth, consequently hydrogen is formed. The hydrogen passes into vast caverns and mixes with air. Any spontaneous combustion in the earth, for which there are many causes, would explode the gas; which explosion, if of sufficient extent, would cause an earthquake.

Prop. 2. *Hydrogen gas burns in a continued blaze, when passed from any vessel into atmospheric air.*

Illustration. Put some of the gas into a tubulated bell-glass or common gas-holder, and immerse it beneath the surface of the water in the cistern; having previously fitted a pipestem into a cork with which the tubulature or hole in the top of the gas-holder, is stopped, the upper end of the pipestem being also stopped with a peg. Pull out the peg, and at the same instant apply a candle to the stream of hydrogen which is forced out by the pressure of the water, and it will be lighted and burn steadily with some degree of decripitation. If a stop cock be used, which is better, no peg will be wanted in the end of the pipe.

Rationale. The hydrogen, and oxygen of the atmosphere unite and form water. Caloric is then forced out, as explained under caloric at the 15th proposition.

Application. This flame was formerly called the philosophic candle; though it was exhibited in a very simple manner. It does not give so much light as some of its compounds, and is not now used for gas lights.

Prop. 3. *Hydrogen gas explodes if inflamed when intermixed with oxygen—very violently if the oxygen is pure, considerably when the oxygen is combined with nitrogen as in atmospheric air.*

Illustration. Mix a quantity of hydrogen and atmospheric air in a tumbler or small bell-glass, one part of hydrogen to two of air by bulk. Fill the gas-pistol with water, hold the thumb on the vent hole, or stop it with a peg, and set the mouth over one of the funnel holes in the shelf. Pour under and fill the gas-pistol with the mixture of air and hydrogen. Having a suitable cork ready and well soaked in water, stop the mouth of the pistol very tight with it. Now raise up the pistol, elevating the mouth so as to point above the heads of the class; remove the thumb from the vent, and at the same instant touch the flame of a candle to it. It will explode and drive the cork to a distance. But if the mixture be made of equal parts of pure oxygen and hydrogen, the explosion will be much more violent.

Rationale. During the explosion, the two gases combine and form water. As the volume of water is much smaller than the volume of the gases, a question naturally arises, why is not the cork driven into the pistol instead of being driven out with such force? If the two gases united instantaneously throughout the whole pistol, the cork would be pressed inwards. But their combination is progressive, from the vent hole to the muzzle; and the heat, consequently the expansion of the uncombined gases, outruns the process of combination.

Application. This exhibits the principle of earthquakes before referred to. Also the inflammability of hydrogen, and shows that oxygen is a supporter of combustion.

Prop. 4. *Hydrogen gas, though itself combustible, will not support the combustion of other substances.*

Illustration. Fill a glass cylinder, or opodeldoc vial, with hydrogen gas. Raise it up slowly, still retaining it in its inverted position, and carefully settle it down over a candle. When the gas touches the flame it will slightly explode. After it is so far settled down over the candle as to bring the wick within the gas, it will be extinguished.

Rationale. The vessel containing the gas is raised with the closed end upwards, because the gas is much lighter than atmospheric air. The slight explosion at the mouth of the vessel occurs in consequence of the mixture of the hydrogen at the mouth with the oxygen of the atmosphere.

Application. The distinction between a combustible substance and a supporter of combustion, should be well settled in the mind of the student. Hydrogen and oxygen are good specimens.

Prop. 5. *Hydrogen and oxygen, when united by combustion, form water.*

Illustration. Fit a stop-cock into the top of a wooden gas-holder or tubulated bell-glass. To the upper end of the stop-cock fit a lead pipe about one inch and a half in length. Cut off a wine-glass, with a triangular file, so far above the bottom as to leave a hole equal to the size of the lead tube. Fit the glass so that it may stand upon the upper end of the stop-cock with the lead tube extending into it through the hole in the bottom. The glass is to be half full of mercury when used. Fit a pipe stem into the end of the leaden pipe, so that it shall stand upright through the mercury to the height of about two inches above it. Having put a sufficient quantity of hydrogen into the gas-holder, turn the stop and let a small quantity of

the gas pass out, which must be lighted up by applying a candle to the end of the pipe stem. Regulate the blaze by the stop, making it as small as it will burn. But if the blaze is extremely small, it will not burn in the oxygen.

Having previously filled entirely full a perfectly dry 8 ounce vial with oxygen, stop it with the finger and raise it up and shut it down suddenly over the burning hydrogen, bringing its mouth down to the mercury. It will continue to burn, but will not explode. At length the blaze will become broader, and finally cease. At that instant turn the stop. On examination the vial will be found to be lined with fine drops of water, and some will run down upon the mercury. No atmospheric air will unite with the oxygen; because, as soon as the blaze comes within the oxygen gas it will expand with the heat, and thus it will be partly forced out while the vial is settling down towards the mercury, and of course prevent the entrance of air.

The best method for filling the vial with oxygen so as to keep it dry, is, to fill it from a bladder, or from a tubulated bell-glass immersed in the cistern. In either case, let the vial stand upright, and force the oxygen to the bottom of it by extending the tube to the bottom. Force in about thrice as much oxygen as would be sufficient to fill the vial, which will entirely clear it from atmospheric air.

Rationale. By this mode of burning the two gases, every thing is excluded which can possibly affect the new compound. It follows that water is formed, in the state of vapour, in this case, by the combustion and consequent combination of oxygen and hydrogen.

• **Application.** From this experiment it appears, that the burning of one of the most combustible substances with the all powerful supporter of combustion, the liquid is produced which we apply to extinguish flame. Attempts have been made to decompose water with charcoal, so that a perpetual supply of hydrogen may be added as a fuel.

Prop. 6. *While hydrogen is burning in oxygen, it excites vibrations in a glass vessel, producing sounds.*

• **Illustration.** While the above apparatus remains unmoved, light up the hydrogen as before, take up a small decanter of oxygen which was filled in the cistern, stopping its mouth, quickly shut it down over the burning hydrogen so as to bring the mouth very near the mercury, but not quite touch it. The decanter will immediately commence ringing, and if every thing is conducted judiciously, with a suitable glass, &c. the sound will almost deafen all present. I think the common bottles used for preserving citrons and other sweet-meats, is the best form. In these the neck is broad and about one third the length of the body.

Keeping the flame chiefly in the neck, while the tip of the flame ascends beyond the shoulder into the broadest part, produces a greater effect. When the sound grows faint, turn the stop a little, so as to enlarge the stream of hydrogen, or fill the jar again with oxygen.

Rationale. The most reasonable explanation given for these vibrations appears to be; that the succession of globules of water, which are formed, strike against the sides of the glass, with such force as to cause the ringing. By suspending

fine asbestos threads within the vessel, it may be seen that these globules do move with much velocity.

Application. Whatever hypothesis we may choose to adopt, the doctrine of sound, as produced by the vibration of elastic bodies, is well illustrated by this experiment. A very amusing musical instrument might be constructed, by suspending different sized glass vessels over a horizontal tube, with lateral keyed outlets, passing into the vessels.

Prop. 7. *Hydrogen is much lighter than atmospheric air.*

Illustration. Fit a tobacco pipe to the end of a flexible tube. Attach the tube to a stop-cock which is fitted to the top of a gas-holder. Set a bowl of strong soap suds on a table near the cistern. Having put a large quantity of hydrogen into the gas-holder, turn the stop so as to let out the gas slowly. By applying the pipe bowl to the soap suds, bubbles may be inflated with the hydrogen gas and shaken off, as children inflate them with their breath and throw them. But instead of falling downward as when inflated with the breath, they will ascend and rise to the upper ceiling.

Rationale. The soap suds being an adhesive liquid, is blown into bubbles by the stream of hydrogen gas which is forced into it by the pressure of water in the cistern. When the bubble attains to such a size that the difference between the weight of the hydrogen gas and the atmospheric air is sufficient to overcome the weight of the soap suds employed in making the bubble, it ascends.

Application. This is the gas with which balloons are inflated. It being but about a thirteenth as heavy as atmospheric air, a large balloon, when inflated with it, will carry up several persons.

Prop. 8. *Water absorbs and holds in combination a quantity of atmospheric air.*

Illustration. Fill the bulb and part of the neck of a bolthead, or a florence flask may do, with river water, or any water which has been considerably agitated in the open air. Tie a thread around the neck at the precise surface of the water. Now suspend it over a candle, or over burning coals, and the water will rise in the neck. Let the heat be continued a little while, but not so as to commence boiling, and numerous bubbles of air will be disengaged and appear in the vessel.

Rationale. The particles of atmospheric air, which are in water, are too minute to be visible. But on being heated their volumes become enlarged, as explained in the 6th Prop. under Caloric.

Application. Air gives to water in running streams a kind of briskness, as it is commonly called, which is not found in the water of wells; and on agitating well water a short time in open air it is greatly improved for drinking. The air contained in water is essential to the lives of fish, which has been often shewn by experiment.—Some species of fish cannot live in a small still fish pond, which would be healthy if the water was frequently agitated, so as to give it a better opportunity to absorb air.

A remarkable fact, which is asserted by the raftsmen on the Hudson river above the head of

tide water, requires particular investigation. They assert, that their mouths become sore, and a sensation is experienced as after a long continued use of vinegar and water, whenever they practice drinking the water of the river. It should be added, that in this part of the river the water is much agitated in the rafting season, which is the spring.

Prop. 9. *Water on freezing expands its volume and thereby diminishes its specific gravity.*

Illustration. Lay a piece of ice on water and it will float. Glass vessels are broken in which water is left to freeze, unless they diverge upwards so much as to allow the ice to rise up when the freezing process commences.

Rationale. By an effort to shoot into crystals, probably very minute interstices are formed in the ice. In addition to this, when the water becomes solid, caloric is pressed out and enters the minute particles of air contained in the water and enlarges their volume, as explained under the 6th and 14th Prop. of Caloric. If this hypothesis is not demonstrated, it is better to adopt it for the present, than to substitute an anomaly by saying water is an exception to the general law.

Application. To this principle we are indebted for our bridges, erected by nature for the boisterous season of winter. Thus too rocks are split down and broken into soils.

Prop. 10. *The specific gravity of water is increased by dissolving a salt in it.*

Illustration. Fill two tumblers almost full of water. Let the water of one tumbler be pure, and that of the other contain as much common salt as it will hold at the temperature of pretty cool wa-

ter. Attach a piece of lead to a small block of wood, whittling off from either the lead or the wood until it will barely float in the tumbler of salt water. Now put it into the tumbler of fresh water and it will sink to the bottom.

Rationale. Salt being strongly attracted by water, combines with it closely, and probably enters the interstices between its particles, giving it a more dense consistency, of course greater specific gravity.

Application. A ship will swim in the ocean with a freight so heavy, that it would sink if sailed into a fresh water river. Persons cast away at sea can swim much easier than they could in fresh water, because the greater specific gravity of the water will help to buoy them up.

NITROGEN.*

Natural History and general Remarks.

Nitrogen is one of the two constituents of the atmosphere; composing about 79 per cent of it. Nitrogen and oxygen are the only essential constituents of the atmosphere; though other gases, as well as aqueous vapour, are always suspended in it. It may be easily divested of these substances by operating upon an enclosed portion of it; and then only it may be called pure atmospheric air. Some authors have set down aqueous vapour and carbonic acid as constituent parts of the atmosphere. But I can perceive no better reason for treating them as essential constituents of the atmosphere, than for treating carburetted hydro-

* I am very glad to find *nitrogen* used by Brande instead of *azote*, which Gorham has very unadvisedly adopted.

gen, ammonia, or floating dust, as such. Or for treating mud and drift-wood as essential constituents of the Hudson, or of the Thames.

Nitrogen is an essential constituent of saltpetre, from which it derived its name. It is also produced in a pure state from the earth at New-Lebanon Springs and in Hosick, in the state of New-York. See Prop. 4, under this head.

Prop. 1. Nitrogen and oxygen being the only essential constituents of atmospheric air, if the oxygen be abstracted from an enclosed portion of the atmosphere, the nitrogen will be left in the state of gas.

Illustration. The oxygen may be extracted by burning phosphorus in an enclosed portion of atmospheric air; or more perfectly if the season is not cold, as follows: Mix finely pulverised sulphur and iron filings, rubbing them well together. Then moisten the mixture with water, and place as much of it on the bottom of an inverted wine-glass as will lie on it, or place it on any other stand of about the same height. Place this on a shelf of the cistern, or in a large soup plate filled with water. Now shut over this mixture a half gallon bell-glass, or specie bottle of that size, and let it stand about twenty-four hours. The oxygen will be absorbed from the air in the bell-glass, and the water will have ascended to fill the vacancy made by the loss of the oxygen, which is about twenty-one per cent. The remaining gas will be nitrogen.

Rationale. Phosphorus attracts oxygen so strongly that its combustion will continue until very nearly the last atom of oxygen is exhausted. The paste of iron filings and sulphur, however,

will absorb, probably, the very last atom. But the process is slow and difficult to be explained.

Application. Whatever consumes the oxygen of the air in a close room, will tend to leave an encreased proportion of nitrogen. Probably the prisoners crowded into the Black Hole of Calcutta, had but very little oxygen to breathe for some time before they died.

Prop. 2. *Nitrogen gas extinguishes flame and destroys life, if breathed, by excluding oxygen.*

Illustration. Immerse a burning candle in an 8 ounce vial of it, it will be extinguished. Fill a small jar or large mouth vial entirely full of the gas, and turn it up. Take a live mouse into the hand, having a leathern glove on it to defend it from the bite of the mouse, and drop it into the jar, instantly covering it again. The mouse will expire in a short time, though not so soon as in some other gases.

Rationale. The candle is extinguished and the mouse is killed, by excluding oxygen; which is essential to the support of combustion and of life. But this gas does not operate as an active agent in the destruction of life, like carbonic acid gas.

Application. Since oxygen and nitrogen are the only essential constituents of the atmosphere, and since nitrogen extinguishes flame and destroys life, it is manifest that oxygen is the only supporter of combustion and animal respiration in the atmosphere.

Prop. 3. *Nitrogen gas is the lightest of the constituents of atmospheric air.*

Illustration. Extinguish a candle as before

directed in a vial of nitrogen gas. Then cover it loosely with dry paste-board, so that the motion of the air may not drive it out, and let it stand a while. Afterwards, or at least after a few trials, the candle will not be extinguished.

Rationale. Nitrogen, being lighter than the atmospheric air, ascends like all lighter bodies when immersed in heavier liquids or gases; while common air takes its place in the vial.

Application. Though oxygen and nitrogen in open space, mix in an equilibrium proportion; when one of them is in excess, or in any manner separated from its state of union, it will seek its place according to its specific gravity. Consequently a disunited quantity of oxygen will settle downwards, and that of nitrogen will ascend. So that when much oxygen is consumed by a crowd of persons in a close room, the excess of nitrogen will ascend and render the air near the upper ceiling very unfit for breathing, while the air lower down is more suitable for respiration.

Prop. 4. *About seventy-nine per cent of nitrogen gas mixed with twenty-one per cent of oxygen, will form artificial air, in all respects similar to atmospheric air.*

Illustration. Take four 8 ounce vials, as nearly equal in size and form as can be procured, and fill them as follows: The first with nitrogen, the second with oxygen, the third with four measures of nitrogen and one measure of oxygen, and let the fourth remain with atmospheric air. Turn them all up, leaving them covered with pieces of wet paste-board, excepting the fourth which may be open. Light a short piece of wax taper which is suspended by a wire coiled round at its lower

end. Let it burn some time with a large wick, which should be spread out wide and full of sparks. Now immerse the blazing candle in the nitrogen, and it will be extinguished—then quickly immerse it in the oxygen and it will be re-lighted—next immerse it alternately several times in the cylinders of artificial and natural air, and it will burn alike in both.

Rationale. The wick of the candle is not acted on positively by the nitrogen; but stops burning merely on account of the exclusion of oxygen. It therefore remains sufficiently heated to continue the flame, as soon as it receives a supply of pure oxygen. As the candle burns in the artificial air just as it does in the natural, it is manifest that the natural and artificial are similar; at least so far as respects combustion. Since the appearance of a burning candle is different, when confined in a vial, from its appearance in open air, it is necessary to immerse it in a vial of natural air when comparing with its appearance in artificial air.

Application. By this experiment we see at one view the nature of the two constituents of the air in their separate and in their combined state. Though these proportions are temporarily varied in the atmosphere of confined rooms, and sometimes in large cities and other places, nature has provided remedies for such contingencies. A considerable supply of oxygen is drawn from the vegetable kingdom, which was illustrated under oxygen. There are other means prescribed for equalizing the proportions of those gases, according to their equilibrium principle.

The production of the nitrogen cannot always

be accounted for. There is a small hill or rather an ascent of ground in the town of Hosick, in the state of New-York, from which continually issues immense quantities of nitrogen gas. Wherever the little rivulets pass over any part of four or five acres of this hill, nitrogen gas continually bubbles through the water.*

Prop. 5. *Atmospheric air holds in suspension more or less of aqueous vapour.*

Illustration. Put a little common table salt into a wine-glass, and pour on it strong sulphuric acid sufficient to wet it. Muriatic acid gas will be disengaged, and condense aqueous vapour so as to become visible, and appear like steam.

Rationale. Muriatic acid is invisible, as shewn under chlorine; where it was also shewn, that it strongly attracts water. When discharged into the atmosphere, its attraction for water brings together numerous invisible particles of vapour, which becomes a visible vapour when thus aggregated.

Application. This experiment demonstrates, that clouds are not the only repositories of aqueous vapour in the atmosphere; but that it is held in suspension in its most clear and transparent state.

Prop. 6. *Nitrogen is found combined with its highest proportion of oxygen in the saltpetre, from which it may be obtained by elective affinity.*

Illustration. Put into a tubulated pint retort about a wine-glass full of pulverized saltpetre,

* Dr. L. C. Beck and myself collected and tested this gas on the 17th of Aug. 1821. It is situated near the east boundary of the state of N. York, about 6 miles S. W. from Bennington, Vt. Vid. Report of the Geological Survey of Rensselaer county, p. 29.

and pour upon it, through the tubulature, strong sulphuric acid sufficient to wet it, or about two thirds as much by weight as there is of the saltpetre. Having previously luted the neck of the retort into a receiver containing a gill of water which has a stoppered tubulature ; now set the retort into a lead pot with coals and raise the heat very moderately. Leave out the stopper a while, for the air to pass out. Then put in the stopper rather loosely, but regulate it according to the pressure of the gas. The nitric acid, (aqua fortis) will come over in the state of gas, or rather in connexion with the vapour of water. It will be absorbed by the water of the receiver. After the process is finished, pass around some of the acid in wine glasses with a rod, and the class will recognize the taste of diluted aqua fortis, or nitric acid.

Rationale. Saltpetre consists of nitric acid and potash. Potash has a stronger affinity for sulphuric than for nitric acid. Of course it elects the sulphuric and excludes the nitric. Such is the nature of nitric acid, that at the common temperature it takes to itself, from the surrounding bodies, a sufficient quantity of caloric to become a gas or vapour.

Application. On this principle the aqua fortis of the shops is manufactured. Iron retorts are used in the manufacture of it in the large way ; therefore it will generally give the test of iron with prussic acid. As saltpetre always contains muriate of soda, muriatic acid will be contained in the aqua fortis of the shops ; consequently will generally dissolve gold, unless it is removed by nitrate of silver, (lunar caustic).

Remark. It is difficult to operate upon this acid, while uncombined with water ; as it cannot be collected over water or mercury. But as it is more than twice as heavy as atmospheric air, it may be collected in a dry vial, as directed for muriatic acid gas.

Prop. 7. *Nitric acid may be reduced to nitrous acid and nitric oxid, by yielding part of its oxygen to a metal.*

Illustration. Put into a very small retort, a gill retort is best, a table spoonful of copper filings—about one fourth as much mercury will do, but not so well. Then pour into it about two spoonfuls of nitric acid, diluted with three or four times as much water. Put the beak of the retort into the cistern under a receiver, and apply the heat of a candle or a pan of coals to the retort. The heat must be uniformly applied, or the gas may be a little condensed in the retort, and the water will rush into it. The gas will soon come over ; but the first will be mixed with atmospheric air, of a reddish colour, and should be allowed to escape through the water of the cistern. It will soon pass into the receiver in a colourless state. This gas is the *nitric oxid*, or the deutoxid of nitrogen.

After a sufficient quantity has been collected, fill a small glass cylinder or opodeldoc vial, half full of oxygen (atmospheric air will do) and then fill it up with nitric oxid. It will immediately take another portion of oxygen and become *nitrous acid*. This gas is readily distinguished from the nitric oxid by its deep orange colour and strong attraction for water. If the glass cylinder be turned up and a burning candle be immers-

ed in it, the candle will continue to burn with considerable brilliancy.

Rationale. The copper filings always reduces the acid to an oxid in this case. But such is the affinity of the deutoxid of nitrogen for oxygen, that it passes almost instantaneously through the hyponitrous to the nitrous state—that is, it becomes the orange nitrous gas, which is rapidly absorbed by water.

Application. In this experiment we begin with the highest state of oxidation which nitrogen is capable of. In this state only it is found in nature. We then obtain the lower acids and the oxids. In the manufacture of nitric acid, more or less of this acid is found combined with it. It is this which passes off in fumes on unstopping a bottle of nitric acid of the shops.

Prop. 8. *Nitric acid may be reduced to nitrous oxid (the exhilirating gas) by heating it when chemically combined with ammonia.*

Illustration. Prepare the salt called nitrate of ammonia, according to the directions to be given under ammonia. If the salt is prepared in crystals, let them be melted and evaporated to a dry powder in an open earthen plate with a slow heat. But it is much better to evaporate it to dryness, with so much heat as to prevent crystallization. Put the salt into a retort, which may be about one fourth part filled. Apply a lead tube to the beak of the retort about three feet long, to prevent accidents, which generally happen without it, by breaking the retort with water when highly heated. No luting is necessary, wet tow or flax will be sufficient. Now set the retort into a lead pot with

coals, and raise the heat with the hand bellows. After the salt has melted, and when vapours begin to appear in the retort, apply the beak to the cistern under the receiver. A great quantity of the gas will soon come over; and it will continue until all the salt, or nearly all, disappears.

This nitrous oxid gas may be breathed in small quantities by the members of the class, about a pint to each, without injury. It will exhilarate slightly, and the taste is sweetish and pleasant. If breathed in large quantities, as about two gallons at once, and respired a dozen times, it intoxicates and suspends the power of reasoning. It is unquestionably injurious to health; but being generally administered to the young and healthy, they endure it, mostly, without any bad consequences. Brande says it cannot be breathed with impunity.*

A burning candle let down into this gas has its flame increased, and it is always surrounded with a purplish ring or halo.

Rationale. By these two last illustrations it appears, that nitrogen combines with oxygen in five definite proportions. And that, beginning with the highest proportion it may be reduced to the other four. In reducing it to the lowest state, the nitrous oxid, the rationale is thus given by chemists. The nitrate of ammonia consists of nitric acid combined with ammonia; and ammonia is a compound of nitrogen and hydrogen. When considerable heat is applied to this salt,

* Several persons have lately employed themselves in peddling this gas about the country, who call their vulgar frolicks, lectures on chemistry. All sensible citizens ought to discountenance such gross outrages upon decency, which tend to reduce the science to the level of a puppet-show.

the hydrogen of the ammonia unites with the highest portion of the oxygen of the nitric acid and forms water. This comes over in the state of white vapour, which appears first. The nitric is thus reduced to a lower state of oxidation. At the same time the nitrogen of the ammonia takes away another proportion of oxygen and becomes nitrous oxid, leaving to the nitrogen of the nitric acid just oxygen enough to form nitrous oxid also.

Application. This gas was at one time thought to be useful in medicine ; but its use seems now to be doubted. The experiment is instructive, as it presents an interesting view of complicated decomposition.

Prop. 9. *Nitrogen and hydrogen combined form an alkaline compound called ammonia, hartshorn, or volatile alkali.*

Illustration. Fill a florence flask with nitrogen. Pulverize iron filings so as to make them almost into an impalpable powder. Pour a small quantity of water upon them, so as to be enabled to make them adhere in the form of little balls, twice or thrice the size of peas. Drop about a dozen of these balls into the flask—care being taken not to leave the flask open but an instant at a time when dropping in the balls ; as the nitrogen will ascend. After several days small quantities of ammonia will be produced. This may barely be perceived by the scent ; but if muriatic acid gas be passed into the flask, muriate of ammonia, or sal ammoniac, will be formed in a small quantity and adhere to the side of the flask.

A much better method for illustrating this proposition is, to decompose ammonia. Make holes a little below the middle of a lead pot so that a

long tobacco pipe may be passed through it in the hottest place. Lute a small retort (a florence flask will do) to one end of the pipe containing dry lime and sal ammoniac. To the other end attach a leaden pipe, so bent as to enter a bowl of water. Raise the heat in the lead pot till the tube begins to be red. Now apply a candle to the retort. Ammoniacal gas will pass into the heated tube and be decomposed. Hydrogen and nitrogen gases will pass into the bowl of water and may be collected in the usual way.

Rationale. When hydrogen and nitrogen are mixed, having been previously prepared, they will not combine to form ammonia. But if hydrogen comes in contact with nearly pure nitrogen, at the instant of its disengagement from the oxygen of the water, it combines with it. In this evanescent state only, it seems that the composition can be effected.

The last experiment merely demonstrates, that the two constituents of ammonia will separate on being heated.

Application. These experiments demonstrate the compound nature of ammonia. But as ammonia is produced in great abundance in nature, and has most of its properties in common with the alkalies, it will be treated in connexion with the other alkalies, whose bases are metalloids.

SULPHUR.

Natural History and general Remarks.

Sulphur is very abundant in nature. It is generally found in combination with a metal, which is called a sulphuret. In combination with iron,

called iron pyrites, it is found in every rock from the oldest granite to the most recent secondary rock. From its combination with this metal and with copper, the brimstone of the shops is obtained by the process called sublimation.

It is found in combination with lead, zinc, silver, mercury, &c. It is also found pure in Italy and in other volcanic districts.

It is inflammable and electrical. It is tasteless and inodorous when pure; but on combining with oxygen by combustion, or by heat or warmth below combustion, it gives off a disgusting odour or suffocating gas.

It crackles by the warmth of the hand. It may be crystallized by melting, and then by pouring out the melted interior of the mass, just at the precise time the exterior is beginning to be covered with an incrustation, by cooling. The crystals are acicular.

Prop. 1. *Sulphur on being inflamed in atmospheric air, will unite with a definite proportion of oxygen and form sulphurous acid gas.*

Illustration. Cover the bottom of a small plate a quarter of an inch deep with water. Put a small piece of common brimstone upon a sheet iron bench set in the plate, which is sufficiently heated to inflame the brimstone, and shut over it a tubulated bell-glass, or a tumbler with a hole in the bottom. This vessel must be of a size just to shut down within the rim of the plate. At first take the stopper out and raise the bell-glass a little above the water, to give passage to a current of air. Regulate this by the progress of the burning sulphur. After the bell-glass appears well filled with a white vapour, shut it down close and tight.

on the stopper. The water in the plate will absorb the sulphurous acid gas in about five minutes. Pour part of this water into wine glasses and pass it around, and the class will perceive the nauseous sulphurous astringent taste, peculiar to this acid. In the mean time wet several substances, coloured with vegetable colouring matter, and it will extinguish many of them, but not all. A yellow straw braid becomes whitened in it; and some colours on calico will be extinguished. The liquid sulphurous acid loses this property by keeping long.

Rationale. It seems that though sulphur is highly inflammable, it will not receive its highest proportion of oxygen while in a gaseous state. For if burned in pure oxygen, sulphurous acid will be produced. When colours are extinguished by sulphurous acid, it is decomposed. From this it appears, that its disengaged oxygen produces the effect, like the oxygen disengaged when chlorine is reduced to muriatic acid.

Application. This acid is used by milliners both in the liquid and in the gaseous state, for bleaching straw bonnets. If old yellow straw braid is soaked a while in water and then suspended inside of a no-headed barrel or hogshead, and brimstone is inflamed at the bottom of the cask and suffered to commence burning thoroughly, then the top covered over, the straw will soon become whitened by the action of this acid. It is also used for killing bees when taking up a hive, and for killing insects to preserve in a collection.

Prop. 2. *Sulphur, on being inflamed in atmospheric air, if previously pulverized and mixed with*

a portion of saltpetre, will unite with its highest definite proportion of oxygen and form sulphuric acid, or oil of vitriol.

Illustration. Dry some saltpetre on a plate. Then pulverize it very thoroughly, and mix it with about four times as much sulphur, (in the large way, eight times as much sulphur is used,) and rub them intimately together. Now proceed in all respects as in producing sulphurous acid, above described; and the additional portion of oxygen furnished by the saltpetre will perfect the process. After the water has absorbed the acid, pass some of it around in wine glasses with tasting-rods, and the class will recognize the clean pleasant sour taste of the sulphuric acid, or oil of vitriol, in a weak or diluted state. It is distinguished from all other acids by its charring or blackening vegetable substances.

Rationale. Under the preceding proposition the sulphur combines with the proportion of oxygen requisite for producing sulphurous acid. The saltpetre, being in immediate contact, furnishes the next proportion and produces the sulphuric acid.

Application. The oil of vitriol of the shops is made on the same principle. Leaden chambers being substituted for the bell-glass, and the floor is covered with water. It is at first obtained in a very diluted state. It is then slowly evaporated, until it comes to a suitable strength for the market. When this, or any other acid, is combined with the smallest quantity of water, which can hold it in the liquid state, it is called concentrated acid. To produce this, the acid itself is distilled over, after the evaporation of the water is finished. But

almost any experiment may be performed with the acid which is prepared by slowly evaporating the water from it in an open plate.

Remark. Sulphuric acid is the key to most chemical analyses. It is made by a direct process. Whereas nitric acid and muriatic acid, being the other two powerful acids, are obtained from saltpetre and from common table salt, by the agency of sulphuric acid.

Prop. 3. *Sulphur may be combined with hydrogen and form the bases of most of the nauseous scents, called sulphuretted hydrogen gas.*

Illustration. Mix about equal bulks of finely pulverized iron filings and pulverized sulphur. Put this mixture into a crucible; covering it over by inverting in it the crucible next smaller in size, of the nest of crucibles to which it belongs. Set it upon hot coals and melt the mixture—let it remain until the blue blaze, which leaks out between the crucibles, ceases. Now empty it out, which will be the artificial *sulphuret of iron*. Next proceed with this in all respects, as directed for obtaining hydrogen gas, with this addition; that after the sulphuret and the diluted sulphuric acid are mixed in the retort, the heat of the candle must be applied to the retort.

This gas must not be collected in the cistern; but the receiver must be filled with pure clean rain or river water and inverted in a wash-bowl or some other convenient vessel, so that no metallic substance shall touch the water.

Rationale. The iron part of the sulphuret acts in some measure as it does in the production of hydrogen gas, but not so powerfully. Therefore

the aid of heat is required to strengthen the affinity. When the hydrogen is thus disengaged from the oxygen of the water, sulphur unites with it, and a compound gas is produced.

Application. This is the gas which is generated in all dirty sinks, and other places abounding in such filthy substances. It is so destructive to life, that a horse will die in a few minutes if covered with a cloth and exposed to it, when introduced under the covering.

Prop. 4. *Sulphuretted hydrogen gas explodes on being inflamed in oxygen.*

Illustration. Mix it with oxygen and explode it in the gas pistol in all respects as directed with pure hydrogen.

Rationale. Same as given for the explosion of hydrogen.

Application. There may possibly be a sufficient quantity of this gas generated about the kitchens and sinks of filthy housekeepers, to explode with the oxygen of the atmosphere. This would be a dangerous method of purification "by fire." Earthquakes are supposed to be caused by the explosion of this gas in most cases; because the smell is perceived wherever an opening is made by the explosion.

Prop. 5. *Sulphuretted hydrogen gas is absorbed rapidly by water; and, in the liquid state, gives a dark or black tinge to many metals.*

Illustration. While the gas is coming over, as before mentioned, let some pass into a decanter, which is filled with rain water and inverted, until half the water runs out. Put the thumb over the mouth and shake the decanter violently. It will

immediately absorb the gas. Now pour a little into a wine glass and drop in a little sugar of lead and it will be blackened. Copperas, blue vitriol, white vitriol, and other metallic salts may be dropped into different glasses of the liquid, and all will receive different shades of colour. A piece of silver coin will also become brown if immersed in it a while, especially in the roughest parts of it.

Rationale. There is some difficulty in giving a satisfactory reason for these various appearances of metallic oxids. As a portion of the gas is always decomposed during the process, it is probable that a sulphuret, more or less perfect, is formed with the metal.

Application. When lead is suspended in water, this liquid is a ready test. Silver spoons, &c. often exhibit dark coloured spots, which appear unaccountable to housekeepers. These are generally caused by liquid sulphuretted hydrogen, generated about filthy sinks, &c. Ladies who paint their faces with a cosmetic, whose base is bismuth or other metal, often become tawny by approaching an old dock or sewer.

Many natural springs are highly charged with sulphuretted hydrogen. They are always useful in cutaneous eruptions; and are generally called Harrowgate springs, from their resembling the Harrowgate waters in England. They are distinguished by the smell of sulphur, or by testing with sugar of lead.

PHOSPHORUS.

Natural History and general Remarks.

Phosphorus, the most combustible of all simple

solids, is always found in nature in the state of an acid; mostly forming a salt with lime. Bones of animals consist chiefly of phosphoric acid and lime.

But phosphorus is not a recently created substance. In truth, it seems that all material substances were created at the same time. For we find those which appear to us the most recent, fugitive, changeable and transitive, in connection with those which we are disposed to consider the oldest and most permanent. Phosphate of lime, a compound similar to animal bones, is found in the oldest granite; though rarely in transition or secondary rocks.

The process for obtaining phosphorus is too laborious and difficult, to be performed in the course proposed in this work. It is obtained from animal bones. The lime is easily disposed of by soaking the bones in diluted sulphuric acid, after they have been burned to whiteness and pulverized. But to separate the oxygen from the phosphorus, after the phosphoric acid is freed from the lime, requires a high and long continued heat; and it requires considerable experience to conduct this part of the process with success. It may be purchased at a dollar and a half or two dollars per ounce. Half an ounce will be sufficient for a course of instruction.

Prop. 1. Phosphorus decomposes water, slowly when the water is in the liquid state, but with considerable rapidity when in the vaporous state.

Illustration. Expose a stick of phosphorus to water several days in a vial, and the outside will be covered with a white substance, which is the oxid of phosphorus. The oxid is more inflamma-

ble than pure phosphorus. If a little be scraped off and exposed to the rays of the sun, in a short time it will take fire.

Put water into a small vial or test glass (previously filled with nitrogen gas) just sufficient to cover the bottom. Then put in a stick of phosphorus, and cork it perfectly tight. Set it in a warm room a few days, and the outside of the stick of phosphorus will be covered with phosphoric acid.

Rationale. In the first case the strength of affinity but feebly decomposes the water in the liquid state. In the last case the small quantity of water passing into a state of vapour is more easily decomposed.

Application. Sticks of phosphorus kept in vials of water in the common way, are always covered on the outside with the oxid. I once set a gallipot in a desk in Rutland court-house, Vermont, to the inside of which a little oxid of phosphorus adhered. The weather was extremely cold, and it stood undisturbed and forgotten for several days. At length a crowded assembly occupying the room one evening, and the temperature of the air being considerably raised, it took fire spontaneously and burned rapidly. If a vial be heated a little, and a piece of phosphorus attached to the end of a wire be rubbed about the inside of the vial, in a half melted state, so as to coat it, this will be the phosphoric match vial. This being the oxid of phosphorus, if a little be taken out and exposed to the air, if the weather is not very cold, it will take fire spontaneously. The vial must be kept corked—and even when it is preparing, it may take fire and require the vial to be stopped a moment until it is extinguished.

Prop. 2. *By light friction phosphorus becomes oxidated, and during the process a partial combustion and illumination takes place.*

Illustration. Rub a stick of phosphorus lightly on a board. The phosphorus which is left on the board will be luminous in the dark, and by blowing upon it, undulating waves of light will appear and vanish.

Rationale. Though the phosphorus does not break out into a flame, oxygen unites with it with such force as to disengage sensible heat and light, and to produce an acid or oxid. All combustion is caused by the combination of oxygen with the combustible substance, and all oxidations would produce combustion, did not the process go on too slow to render the disengagement of caloric manifest to the senses. In this case, the light is manifest in the dark.

Application. Letters or even sentences may be written on board ceilings, &c. which may be read in the dark for fifteen or twenty minutes. During their illumination, the phosphorus is manifestly in a state of imperfect combustion, and becomes oxidated.

Prop. 3. *Phosphorus on being inflamed in atmospheric air, will unite with its highest definite proportion of oxygen and form phosphoric acid.*

Illustration. Set on the table a perfectly dry earthen plate. Lay upon the centre of it a piece of a stick of phosphorus one third of an inch in length. Set it on fire and invert over it a perfectly dry half-gallon tubulated bell-glass. Raise one edge of the bell-glass half an inch by inclining it a little towards one side, or placing a chip under it. Start the stopper of the tubulature a

little, so as to permit the nitrogen gas to escape, as the oxygen of the air in the bell-glass becomes exhausted. In this way continue the combustion of the phosphorus until it is nearly consumed. The inside of the bell-glass will exhibit the appearance of a snow-storm, and a considerable depth of dry white phosphoric acid will fall upon the plate. This acid strongly attracts water, like the other acids. It will become liquid, though corked up in a vial, unless much care is taken to make the vial perfectly dry, and to fit in the cork very tight when it is dry.

While the acid remains untouched and dry on the plate, dip a fine shaving brush into cold water and strike it across the finger, so as to sprinkle very fine drops of water upon the dry acid, and minute brilliant sparks will appear. I have not seen any notice of this fact published. It may have been published; but it was, so far as respects my knowledge of the subject, an original discovery made by one of the students of the Rensselaer School. I am not prepared to assign a reason for this appearance.

Rationale. Same as that frequently given already, in regard to the union of acidifyables with oxygen.

Application. This acid is not much used. It is ready formed in animal bones, as before observed. It is used in medicine in combination with soda and some other bases.

Prop. 4. *Phosphorus may be inflamed under water by furnishing it with a due portion of oxygen.*

Illustration. Put a piece of phosphorus into a tall narrow cylindric glass which is filled with

cold water, and put in with it about three times as much oxymuriate of potash. Bring the two substances in contact with each other. Provide a very long tube and stop up the lower end and fill it with sulphuric acid, before it is put into the water. Then press the thumb upon the upper end of the tube and unstop the lower end, at the instant it is to be put in. After the open end of the tube is brought in contact with the salt, the thumb may be raised up and pressed down, so as to furnish the quantity of acid required to continue the flame.

The phosphorus may be inflamed also by forcing a stream of oxygen upon the phosphorus, through a tube from a bladder. But in this case the water must be hot, nearly at boiling heat.

Rationale. Such is the strength of attraction between phosphorus and oxygen, that they will unite and produce combustion even when enveloped in water, whether immediately presented or obtained from a salt.

Application. This experiment has its use in familiarizing our minds with the correct principles of combustion.

Prop. 5. *Phosphorus may be made to unite with hydrogen, forming a compound which explodes and burns spontaneously in atmospheric air, called phosphuretted hydrogen gas.*

Illustration. Procure a tin vessel, called a jack-o'lantern basin, made as follows. Have an inch hole made through the bottom of a tin quart basin. Have a tin quart decanter made with strait sides. Let the mouth of the decanter be soldered to the under side of the basin, so as to fit the hole

in the basin. Now introduce, through the hole in the bottom of the quart basin, into the decanter part, a mixture of two parts of dry newly slacked lime and one of dry pearlash, pouring in occasionally a little cold water, just sufficient for a thick paste, until it is almost filled to the bottom of the basin part. Drop in about two inches of a stick of phosphorus. Stir the whole well, so as to mix all parts thoroughly.

Set the decanter part upon coals, or suspend it over a lamp. Let the heat be raised moderately. Before the mass is to a boiling heat, bubbles of the gas will appear in the neck and explode.

Now fill the neck with water, and lay upon the mouth a piece of lead about two inches in diameter with a hole in the center about the size of a pipe-stem. Fill up the basin with water, which must be occasionally changed by dipping out, when it becomes too warm. Bubbles of gas will rise to the top of the water, explode and form an ascending corona or wreath; but they may sometimes spread over the surface of a very small size. Break off the foot of a wine-glass and use it for a receiver, for collecting and turning up large bubbles, and for transferring gases into a cistern.

Rationale. Phosphorus decomposes water, and unites with the hydrogen of the water in its evanescent state. But it seems to require the presence of an alkali to create in it, in some unexplained manner, a pre-disposition to decompose the water. See Carbon, Prop. 7.

Application. This is an exhibition of the jack-o'lantern, so often seen about places where animal bodies are putrifying in damp ground. But nature has a method of combining the phosphuret-

ted hydrogen with something, which causes it to burn more steadily and to endure longer.

Prop. 6. *Phosphuretted hydrogen gas explodes spontaneously, and with great brilliancy in oxygen gas.*

Illustration. While the bubbles of phosphuretted hydrogen gas are ascending, pass a wine-glass of it under a hole in the shelf, over which is set a strong bell-glass, with about a half pint of oxygen in the upper part of it. After a bubble has ascended through the water of the bell-glass and comes in contact with the oxygen, it will explode with a brilliant illumination. But if any bubbles pass into the oxygen and break without exploding, they will mix with the oxygen and form an explosive compound. Then if succeeding bubbles should explode, the whole would explode and break the bell-glass with some danger to the auditors. Therefore, if this happens, the process must be discontinued, and the oxygen removed. See Silliman's Journal.

Rationale. It seems that the combustible qualities of these two very combustible substances, are strengthened by their union. Though each attracts oxygen powerfully while separate, when combined they even attract it from the atmosphere with sufficient force to explode spontaneously.

Application. This experiment ought to satisfy our minds, that the pretended mysteries of conjurers and showmen are but the application of their smattering knowledge of a few scientific facts.

Prop. 7. *Phosphorus dissolves in warm oil, and in that state is luminous in the dark when exposed to atmospheric air.*

Illustration. Fill an ounce vial two thirds full of sweet oil. Put some shavings of phosphorus into it; about half an inch of a common stick will be sufficient. Hold the vial near the fire, until it is about as hot as can be borne by the hand, and keep it at this temperature until the phosphorus is melted. Now if the cork is taken out, the upper part of the vial will become luminous in the dark by the admission of air. Cover all the lights in the room, pour two or three tea-spoonfuls of it into the hand, and rub it thoroughly over a boy's face and hair, and let him show himself to the class. His face will be singularly luminous, and his hair will exhibit a kind of undulating flame. It must not be forgotten in this experiment, that the vial is to be warm, but not hot, so that the oil may be of a temperature about equal to blood heat whenever it is to be applied, and there must be no unmelted piece of phosphorus.

Rationale. Caloric and light generally accompany each other. Consequently combustion produces light. In this case there is manifestly a partial combustion. This appears from the fact, that when air is admitted by unstopping the vial, it becomes luminous; but on stopping it again it becomes dark as soon as the oxygen of the admitted air is expended.

Application. Although many luminous meteors traverse the atmosphere, called shooting stars, &c. which have never been subjected to analysis; yet these three last experiments go far towards a solution of such phenomena.

PRINCIPLE 5. CARBON.

Natural History and general Remarks.

Carbon is pure in the state of a diamond only.

Common charcoal is always combined with a little oxygen. Carbon is abundant in nature in various states. In the pitcoal it exists in combination with a little oxygen, bitumen, sulphur, &c. In the anthracite or glance coal it is more pure than in any other state, excepting the diamond. Combined with oxygen in the state of gas, it floats in the atmosphere. It forms a constituent part of marble, of chalk, of all vegetable and animal matter, &c.

Carbonate of lime is found disseminated in granite ; therefore carbon is associated with the oldest rocks in the solid state, while we give off portions of it from our lungs in the state of gas at every respiration.

Prop. 1. Charcoal, when cold, absorbs sulphuretted hydrogen gas, ammoniacal gas, carburetted hydrogen gas, carbonic acid gas, &c. and gives them off again when heated.

Illustration. Prepare these gases according to the directions heretofore given, and hereafter to be given : fill small glass cylinders or opodeldoc vials with them separately, and place them over mercury. Cut pieces of charcoal of a size which will easily enter the mouths of the glass cylinders. Take the pieces separately into the small crooked wire tongs and hold them over a hot fire, until they become red hot. Take them from the fire and scrape off the outside a little, and plunge them into mercury to cool without coming in contact with the air. After they are perfectly cooled, pass them separately into the several cylinders of gas, still holding them in the tongs, and a considerable quantity of each will be absorbed, and the mercury will ascend to fill the vacuum. After

these pieces of coal are saturated, draw them out through mercury (at least one or two of them) and heat them again. On applying them a second time, it will be found that the heat has driven out the gases, as they will again absorb them as before.

A little mercury will be found pressed into the pores of the coal; but this does not affect the experiment, as the coal will absorb the gases equally well, though a little slower.

Rationale. The absorbing property of charcoal commences from the moment of its manufacture at the coalpit—consequently it absorbs the first of these gases with which it comes in contact after cooling. By heating, the absorbed gas is disengaged; then on cooling, it again absorbs as above shown.

Application. There is not an experiment known in chemistry, which explains more of the practical principles of agriculture and domestic economy, than this. All the gases which are produced when animal matter passes into a state of putrefaction being absorbed by it, it is very important in resisting and checking the progress of putrefaction. A tooth-powder, made by heating finely pulverized charcoal to redness in an iron skillet, and pouring it while hot into a bowl of clean water, is the best of all known substances to preserve the teeth from decay, or to prevent further decay after it had commenced. For the gases being all driven out by heat, the charcoal absorbs water and sinks in it. If kept in a bottle, it will remain under water, defended from the gases, and if shaken up and a tea-spoonfull be taken occasionally into the mouth, and the teeth rubbed with it, every thing impure will be absorbed.

Putrid meat will become purified by immersing it in a similar preparation. Putrid water is also purified by pouring into it heated charcoal powder, &c. &c.

Carbonaceous manures, as rotted straw, leaves, &c. furnish food for vegetables upon the same principle. In the cool season of night they absorb carbonic acid, carburetted hydrogen, ammonia, &c. which they give off under the heating rays of the sun, during the day, to the absorbent vessels of the fibrous roots of plants.

Prop. 2. *Charcoal, if exposed to oxygen gas in a state of ignition, will combine with it, and form carbonic acid gas.*

Illustration. Fill a glass cylinder or opodeldoc vial, with oxygen gas in the cistern, slip across its mouth a piece of paste-board, turn it up and set it near the mercurial trough. Expose a small piece of charcoal to a strong heat, holding it in the tongs until it is red hot and burning. Now lay it upon the surface of the mercury, and holding the paste-board pressed upon the tumbler, bring it, with the top downwards, over the burning charcoal. Quickly remove the paste board, and shut the tumbler closely over the coal. It will burn, throwing off bright sparks, until so much of it has become a gas and combined with the oxygen, as to convert the whole into carbonic acid. The bulk of the gas will neither increase nor diminish, but become specifically heavier. The oxygen must be perfectly pure.

Now draw out the coal through the mercury, slip the paste-board across the mouth of the tumbler, turn it up and set it on the table. Immerse a burning candle in it, and it will be extinguished.

Test it also with limpid lime water. This may be performed most conveniently, by carefully letting down into it a low glass cup of lime water. It will soon be covered with a white or grey pellicle. A very small watch glass will do, if it is not convenient to obtain any other.

Rationale. Carbon has a strong affinity for oxygen, but will not combine with it, while in a solid state unless its affinity is strengthened by the aid of caloric. As soon as the combination takes place, such is the nature of this compound, that it assumes the gaseous form and remains a permanent gas in every known temperature.

Application. A kettle of burning coals is frequently set into a close bed-room on a cold night. Carbonic acid gas is formed by the union of the charcoal with the oxygen of the atmosphere, which frequently destroys life.

Prop. 3. *Carbonic acid exists in combination with lime, forming chalk, common limestone, or marble, from which it may be obtained by elective affinity.*

Illustration. Pulverize a fragment of marble, and put a wine glass full into a pint retort. Pour on it about a gill of water. After it has soaked about a minute, pour in slowly half a wine glass of sulphuric acid, diluted with about five times as much water. The carbonic acid will come over in a state of gas, and may be collected in any receiver placed on a shelf of the cistern.

Rationale. Lime, which constitutes the basis of the marble, elects the sulphuric acid, and thereby excludes the carbonic acid. The latter acid, as soon as it is eliminated from its connexion with the lime, absorbs caloric from the atmosphere and

other surrounding bodies in sufficient quantities to convert it into a gas, from the solid state in which it existed while it constituted an essential part of the marble.

Application. On this principle the carbonic acid for making acidulous water, improperly called soda water, is obtained. But by what process nature disengages the vast quantity of this gas, which is required to charge the Saratoga and Ballston waters so highly, no one has hitherto suggested even a plausible conjecture.

Prop. 4. *Carbonic acid gas is absorbed by water, and in that state of combination gives the acid test.*

Illustration. Pass some of the gas into a decanter of pure cold water and agitate it, until the water and gas are well mixed. Pour into a wine-glass of it some of the blue infusion of red cabbage, and it will become of a very light red colour. The infusion ought rather to be greenish when put in, by putting into it an extremely small quantity of an alkali before it is used, otherwise the change in colour made by the acidulous water will hardly be perceived.

Rationale. This is one of those primary facts, for which no satisfactory rationale can be given. We can say little more in such cases, than that so is the fact.

Application. This proves the fixed air to be an acid gas. The taste of the water also indicates its acid quality. Carbonated waters, called soda waters, are prepared upon this principle. The quantity of carbonic acid gas, absorbed by the water, depends on the coldness of the water, and

the force applied to compress the gas, while in contact with the water. The waters sold under the name of soda waters, as prepared in most of our towns, contain both sulphurous acid and muriatic acid. Chalk is commonly used, which generally contains a little muriate of soda. This being decomposed furnishes muriatic acid; and it is impossible to avoid a little mixture of sulphurous acid, arising, probably, from a slight decomposition of some portion of the sulphuric acid, used in the process. To cleanse the gas from these deleterious impurities, Mr. Meigs, of Albany, prepares this gas and forces it once through his condenser, containing a small quantity of water, before he introduces the water for use. The small quantity of water readily absorbs all the muriatic acid and sulphurous acid, and wastes a little carbonic acid. This being drawn off and pure water added, the carbonated water is made very pure.

Prop. 5. *Carbonic acid gas is heavier than atmospheric air, extinguishes flame, and destroys life when breathed.*

Illustration. Immerse a candle, suspended by a wire, in a tumbler containing atmospheric air, and let it be observed that it burns as it did in air not contained in the tumbler. Take out the candle and invert a glass cylinder or opodeldoc vial, which is filled with carbonic acid gas, in the tumbler. The cylinder should be smaller than the tumbler, so that its mouth may enter the mouth of the tumbler; and the mouth of the cylinder must be covered with wet paste-board, until it is brought directly over the tumbler. After holding the glass cylinder in this position about eight or ten seconds,

the gas will have settled down into the tumbler. Now immerse the candle again, and it will be extinguished. The gas will remain in the tumbler, and still extinguish a candle for any length of time if a piece of dry paste-board be loosely laid over it, so as to prevent its being driven out by the motion of the air.

Fill a glass cylinder with carbonic acid gas, set it on the table with the mouth upwards, and put a live mouse into it. The mouse will appear convulsed for a moment and expire.

Rationale. Gases, as well as liquids and solids, of the greatest specific gravity, tend to occupy the lowest position. As gases move freely among each other, the heaviest descends of course, unless assisted by the attraction of affinity or of adhesion. In this experiment, it is probable that some of the carbonic acid gas combines with atmospheric air; but after the latter is fully saturated, the former settles at the bottom of the tumbler nearly pure. Its properties are then rendered manifest by extinguishing the candle, &c.

Application. This is the gas usually called choak damps, by miners. Being heavier than atmospheric air, it settles down into wells and caverns, and often destroys the lives of miners. As it is absorbed by water, unless it is very rapidly produced, none will be found to remain in wells which contain water; but it is generally found in deep dry wells, which are dug in very compact earth or in rocks. In all such cases, a candle should be let down before the well is entered. But the gas may be found in wells containing water; for water will not generally absorb more than its bulk of the gas in twenty-four hours, and

a larger quantity may be accumulated in that time, especially in limestone countries.

Prop. 6. Carbonic acid gas may always be found, in a greater or less proportion, suspended in the atmosphere.

Illustration. Pour a tea-spoon of limpid lime water into a clean decanter. Shake it smartly, and the lime water will become milky.

Rationale. The milky appearance of the lime water demonstrates the presence of carbonic acid. As the decanter contained common atmospheric air, the presence of carbonic acid in combination is proved.

Application. Carbonic acid is found to be excellent food for plants, when absorbed by fresh earth, by carbonaceous manure, &c. as before observed. Therefore its suspension in the atmosphere affords an inexhaustible fund of vegetable nutriment.

Prop. 7. Carbonic acid gas is given out by animals at every respiration.

Illustration. Put some limpid lime water into a wine-glass and breathe in it through a tube extending to the bottom of the glass. After thus exciting a bubbling in the lime water five or six seconds, it will become milky.

Rationale. As the milky appearance of lime water has never been produced by any limpid gas excepting the carbonic acid, it is evident that this gas is contained in the breath. That its proportion in the breath is much greater than in the inhaled atmospheric air, may be shown by comparing the different effects produced by blowing the breath into one glass of lime water, and blowing

common air into another from a clean tube fitted to the pipe of a hand bellows.

Application. It was observed under oxygen, that the pure oxygen was given off from vegetables by the action of light; which oxygen is essential to the health and even to the existence of animals. Here we perceive, by this experiment, that animals in return give off carbonic acid, which is most important to the growth of vegetables. Therefore animals and vegetables ought to live near each other.

Prop. 8. *Carbon and hydrogen may be united, forming the light carburetted hydrogen gas, by decomposing water with charcoal. This is called the blue gas, from the colour of its flame.*

Illustration. Collect some pieces of charcoal from an old coalpit bed, or from some other place, where the coal has been exposed to the weather several years, and become intimately combined with water. Dry it, pulverize it, and heat it in a gun-barrel, as directed in procuring oxygen from manganese. The heat must be raised suddenly; for a slow heat will evaporate the water with but very little combination. Collect it in the cistern, and put some into a gas-holder and burn it as directed in burning hydrogen. It will burn with a blue flame, without giving much light.

Rationale. Water being intimately mixed with the charcoal and held in union with it by the attraction of adhesion, by the application of heat the oxygen of the water unites with a portion of the carbon. The water being thus decomposed, its hydrogen unites with another portion of carbon, forming the compound gas.

Application. As in this case the charcoal decomposes the water which it held in combination, and a part of it unites to the hydrogen; so decaying or putrifying vegetables in swamps, &c. decompose water and form the same gas, which is generally called marsh miasmata. It appears too in the bottom of stagnant ponds, &c. which may be collected in bubbles by pressing upon the mulchy sediment.

Prop. 9. *Carburetted hydrogen gas will explode when inflamed with oxygen.*

Illustration. Mix the gases in equal volumes in a bell-glass or tumbler. Pour this into a narrow mouthed bottle or decanter. Sink the bottle under the water of the cistern, holding the thumb over the mouth. Having wet a roll of paper in spirits of turpentine, light it and hold it close to the water over the bottle, and let up the gas in small bubbles. When the bubbles come in contact with the blaze of the turpentine taper, they will explode, exhibiting the cracking of musquetry, firing from under the water.

Rationale. Hydrogen and carbon being both combustible substances, when presented to pure oxygen in the subtle states of a gas, they become inflamed so suddenly as to cause the explosion.

Application. A similar gas mixed with olifant gas, is sometimes generated in coal mines, which coming in contact with the oxygen of the air, often explodes when the workmen go into the pits with candles. But it is found, that if the candle is enclosed by fine wire gauze, called Davy's safety lamp, the gas will not explode. If the instructor has such a net, the class will be highly

gratified with its exhibition, which may be easily made in a large glass jar filled with the mixture of gases just mentioned.

Prop. 10. *Carbon and hydrogen may be united, forming a heavy carburetted hydrogen gas, called olifant gas, by heating alcohol and sulphuric acid together. This is called the white gas, from the colour of its flame.*

Illustration. Put half a wine-glass of alcohol into a deep tubulated retort, pour upon it in a small steady stream about twice as much by measure of strong sulphuric acid. Put in the stopper and apply the candle to the retort, approaching it gradually. The alcohol at first becomes somewhat charred and turns black, soon afterwards the gas comes over. Let a little of the first escape, which consists of atmospheric air and ether. Collect the gas over water. If it contains considerable sulphurous acid it will generally disappear soon while standing over water; but lime water will entirely purify it, if necessary.

Mix it with double its volume of oxygen, and explode it as directed with the light carburetted hydrogen. Also burn it pure in a stream, as directed in burning hydrogen gas, and it will give a very luminous blaze.

Fill a glass cylinder or opodeldoc vial with liquid chlorine. Pass this gas up into it, until about two thirds of the liquid chlorine is displaced. The volume of the gas will be diminished on standing a few seconds, and water will ascend. On the surface of the water will be seen oily masses resembling small drops of tallow. These oily masses give the name, *olifant*.

Rationale. The rationale for the light carburetted hydrogen, applies to the heavy also, with this addition : Alcohol being a vegetable substance, whose chief constituent is carbon, the action of sulphuric acid chars the carbonaceous part. This imperfect charcoal is of a soft yielding texture, and unites more freely with the hydrogen. Thus the higher definite compound is produced.

Application. Both the formation of this gas, when the alcohol becomes charred and its producing an oil when mixed with chlorine, present a curious exhibition of changes produced upon vegetable matter, while passing through different states of combination.

Prop. 11. *Carbon and hydrogen will unite, partly as in the light, and partly as in the heavy carburetted hydrogen gas, by distilling pit coal with a red heat.* This produces the gas used for what is called the gas-light. It is called coal gas.

Illustration. Pulverize some pit-coal, commonly called sea-coal, and heat it in a gun-barrel, as directed in using charcoal, and obtain the gas in the same manner, with the following exceptions : Fit a piece of wood in the form of a half-cylinder, so that it will fill one half of the gun-barrel from end to end. Set it in an oblique position with the empty side downwards, and in this position put in the pulverized coal, so as to fill it about one third of its length. Now put it into the fire with the same side downwards, and after it is placed in the situation in which it is to remain, draw out the piece of wood, leaving the barrel but half filled. When the heat is raised the coal will swell and fill the barrel, which it would burst if

filled at first. The gas will soon come over in abundance, and bring over with it great quantities of mineral tar and bitumen. It should stand over water several hours to let these substances subside. If it is received into the gasholder of the cistern, the water must be drawn off, the cistern washed and filled with clean water before it is used for other purposes. The gas may be exploded with oxygen, and burned in a stream, as directed with light carburetted hydrogen. The blaze will be less white and luminous than of the olifiant gas, and more so than of the carburetted hydrogen.

Rationale. After reading the rationale of the light and heavy carburetted hydrogen, it may be added ; that pit coal always contains a sufficient proportion of water in combination to furnish the necessary proportions of hydrogen. The water being chemically combined in the pit-coal, the gas comes over in a higher state of combination in part ; constituting a mixture of the light and the heavy carburets.

Application. This is the principle on which the gas for the gas-lights is obtained. But the apparatus is so arranged as to obtain it very economically, and purify it without expense. The mineral pitch is preserved for useful purposes. In London seventy-six thousand lights are supported by this gas with 28 chaldrons of coal per day. Messrs. Taylors of England, have lately contrived a method for obtaining a gas for gas-lights very economically from every kind of oil.

A mixed gas consisting of different proportions of the light and heavy, constitutes a large proportion of the fuel of our wood fires. When a billet

of wood is laid upon the fire and becomes heated, the water of the wood is decomposed by the carbon, and carburetted hydrogen gas issues from it at its pores and cleavages. Though it is often mixed with steam, it takes fire and burns with a flame more or less bright according to its proportions of light and heavy carburet. Birch bark, (or rather the cuticle) gives out the heavy carburetted hydrogen almost pure. The flame of the gas may be known by its not extending down to the wood.

PRINCIPLE 6. BORON.

Natural History and general Remarks.

Boron is the basis of boracic acid. The acid is found in the East Indies, Persia, Thibet, &c. combined with soda; forming the salt called borax or tinkal. It is generally found in lakes. It gives the alkaline test, and is therefore called a sub borate of soda.

Boron combined with oxygen in the state of boracic acid, is united to a base of soda, forming borax, from which it may be obtained in solid scales by elective affinity.

Illustration. Dissolve common borax in about six times its bulk of hot water in a gallipot. Then pour into it about half its weight of sulphuric acid. After stirring it on pretty hot coals for five or six minutes, set it by to cool. A decomposition takes place, sulphate of soda is formed which remains in solution, and the boracic acid is disengaged and appears in solid shining scales. Pour off the liquid solution of sulphate of soda, and rinse the scales several times in cold water. Every time

wait for them to separate from the water, in which they can hardly be dissolved. When well washed they are nearly tasteless. Now dissolve some of the boracic acid scales in alcohol on an earthen plate, and set the alcohol on fire with a lighted roll of paper, and as it burns, the points and sides of the flame will be tinged with a beautiful green.

Rationale. Soda has a stronger affinity for sulphuric than for boracic acid. But the difference is not great enough to effect a ready decomposition cold. When heat is applied, the decomposition is effected. The new compound, sulphate of soda, is soluble in water moderately cool, in which boracic acid is solid. This difference in the solubility of the two substances affords the means of separating them as given in the last paragraph.

Application. This experiment exhibits one mineral acid in the solid state when pure. The salt, which this acid forms in combination with soda, is much used in brazing, under the name of borax. It brings brass to the liquid state when thrown upon it, at a temperature considerably below its fusing point. Borax becomes a soluble glass after parting with its water of crystallization before the blow pipe.

PRINCIPLE 7. SELENIUM.

Natural History and general Remarks.

Selenium is an extremely rare substance; having been found by Berzelius in very minute quantities in pyrites from Fahlun, in Sweden. It re-

sembles sulphur more than it does any other substance ; though it approaches the nature of tellurium. It is reddish in minute pieces ; but its fracture is like lead in larger masses. It melts a little above the boiling heat of water. After melting, it becomes soft and adhesive like wax. On being heated more highly it is volatilized in the state of a gaseous oxid of the odour of horse-radish.

CLASS IV. METALLOIDS.

General Remarks.

At this point of a course of instruction in chemistry, the subject takes an essential change. Pneumatic chemistry is chiefly terminated here; though not wholly. We now enter upon that part of the course, which embraces most of what is usually denominated *assaying*. The preceding and following parts of the course are sometimes given in distinct laboratories. The latter often requires very high heat and more earthy and metallic apparatus. Fewer new laws are introduced with the introduction of a new principle. There is more labor and less science, or, as some would say, more of art and less of science presented at every succeeding exercise. Our nomenclature must be further explained before we proceed. The rationale, as a distinct paragraph, will not be given in the remainder of this book. Having been so far instructed, the student should be exercised in furnishing his own rationale, through the remainder of the course. In difficult and in doubtful cases, the teacher should discuss the subject in his lectures.

NOMENCLATURE.

When a salt is composed of a base united with an acid in its highest state of acidification, the name of the acid ends in *ate*—if the acid is in the lowest state of acidification, its name ends in *ite*. As saltpetre is composed of nitric acid and potash, it is called *nitrate* of potash—potash and nitrous acid would be called *nitrite* of potash.

Sometimes the state of the oxidation of the base is expressed by prefixing its degree to the name of the acid. As copperas is sulphuric acid combined with the *protoxid* of iron, it would be *proto-sulphate* of iron. As blue vitriol is sulphuric acid combined with the *deutoxid* of copper, it would be *deuto-sulphate* of copper.

When an acidifiable substance is united to a base without being acidified, it ends in *uret*. As sulphur and iron melted together form *sulphuret* of iron—sulphur and potash, *sulphuret* of potash. When the compounds are both acidifiable substances not metallic or in the state of gas, *uretted* is generally the termination. As *phosphuretted hydrogen gas*, *sulphuretted hydrogen gas*, *carburetted hydrogen gas*.

When two or more metals are combined, they are called *alloys*; unless one of the metals is mercury, when the mixture is called an *amalgam*. When a metal is combined with any substance, excepting another metal, it is said to be *mineralized* with it. This, however, is a term appertaining rather to mineralogy than to chemistry.

SECTION I. BASES OF ALKALIES AND OF ALKALINE EARTHS.

General Remarks.

It is now established, that these alkalies consist of peculiar bases, united to oxygen. These bases have some properties in common with metals; but they differ so widely in other properties, particularly in their specific gravity, that they are denominated *metalloids*. The oxygen may be separated from the bases by a very powerful galvanic

battery, and some of them by other means. And though such experiments are brilliant and very amusing, they have no practical application to the purposes of life. They would be introduced here, however, as well calculated to illustrate principle, were they not attended with too much difficulty and expense for the course proposed in this work.

The alkalies and alkaline earths consist of peculiar metalloidal bases, chemically combined with definite proportions of oxygen. They all give the common alkaline tests. That is, they give a green colour to blue and generally to red vegetable infusions; such as of red cabbage, blue and purple petals of violets, &c. They are all caustic to the taste. They constitute the bases of many important salts, both natural and artificial, as will be shown under each of them respectively.

PRINCIPLE 1. OF POTASH.

Natural History and general Remarks.

As potash is one of the constituents of felspar, (a homogenous mineral aggregated with quartz and mica in granite) it exists in the oldest of the primitive rocks, as well as in animals and vegetables. It is chiefly obtained by lixiviation from the ashes of burned vegetables. It is also a very abundant production of nature in the state of the basis of saltpetre.

Prop. 1. *Potash may be obtained tolerably pure by abstracting the carbonic acid from pearlash by the aid of quick lime.*

Illustration. Dissolve pearlash in about twice its weight of boiling water. Mix this with about as much newly slacked quick lime. Let this stand

about a week corked closely in a bottle, occasionally shaking the mixture. At last let the lime settle to the bottom, and carefully pour off the supernatant liquid, which is the pure caustic potash in solution. But if it be wanted for immediate use, boil the mixture about an hour in an iron kettle, adding water enough to keep it in the state of a cream-like liquid, and the decomposition will be effected. If the potash is wanted in a crystallized state, evaporate the liquid very slowly, just keeping the steam rising from it.

Application. Pearlash, the sub-carbonate of potash, is made while a high heat is applied. Consequently vegetable impurities and most substances contained in common potash are driven out. Now the carbonic acid being withdrawn also, the potash is left nearly pure and severely caustic.—A quantity should always be in readiness in the laboratory, both liquid and solid.

Prop. 2. *Potash has a strong affinity for all animal matter.*

Illustration. Melt a little common potash in an iron ladle, then put into it small bits of fresh meat and woollen rags and boil them a short time. The rags and meat will be dissolved and soap will be formed.

Application. On this principle soap is made by boiling any animal substance with ley, which is a solution of potash. It requires very strong ley, or rather melted potash, to convert rags and some other animal substances into soap. As potash readily becomes diliquescent, as shewn by numerous experiments, soap is always soft or in the state of an imperfect liquid when potash is used.

Prop. 3. *Potash will unite directly with sulphur, and form sulphuret of potash.*

Illustration. Take some dry pearlash and half as much sulphur, mix them and rub them well together. Melt them together in a crucible covered with another crucible, as directed in making sulphuret of iron; excepting that it must be poured out when melted. It must also be corked up in a vial to prevent its diliquescing.

Application. Sulphuretted hydrogen gas may be made with this, as with the sulphuret of iron. It is also used in medicine, and was called liver of sulphur or hepar sulphuris.

Prop. 4. *Potash may be combined with nitric acid, and form nitrate of potash, called saltpetre.*

Illustration. Fill a tumbler half full of diluted nitric acid, consisting of one part of nitric acid to six parts of water. Drop in pearlash, a little at a time, to the point of saturation; that is, until it ceases to effervesce. This will be the nitrate of potash in solution. Now if it is wanted in the state of crystals, evaporate it as heretofore directed.

Application. Saltpetre is found in abundance in nature, combined with a little common salt; therefore it is never made in this way, excepting by way of experiment.

Prop. 5. *Nitrate of potash may be reduced to the nitrite of potash by heating it.*

Illustration. Throw saltpetre upon hot coals. The coals will burn brilliantly a short time. Some of the residue of the saltpetre may be scraped from the coals. This is the nitrite of potash, and

will not cause the brilliant combustion of coals ; because the highest proportion of oxygen is eliminated from the acid and the lower proportions are held by stronger affinity.

Application. The use of saltpetre in the manufactory of gunpowder depends on the easy disengagement of the highest proportion of oxygen from its nitric acid. The oxygen being in immediate contact with the combustible ingredients of the gunpowder (charcoal and sulphur) these solids suddenly become elastic gases.

Prop. 6 *Potash combined with an acid in the definite proportion which constitutes a neutral salt, causes no change in the colour of vegetable blues ; but when the proportion is varied, changes are produced.*

Illustration. Dissolve a piece of saltpetre, of the size of half a pea, in a wine-glass of pure water. Pour a little of it into another glass, containing the blue infusion of red cabbage ; and no change of colour will be produced. Add a drop from a weak solution of potash, to the saltpetre solution, and it will now change the cabbage infusion to green. If dilute nitric acid be added gradually to the saltpetre solution, and stopped at the precise point of saturation, it will not change the colour of the infusion. But ever so small a quantity of the acid in excess will produce a red colour. Thus the saltpetre solution may be made to give red and green colours to the infusion, alternately, any number of times.

The same experiment, if performed with any neutral salt, and the alternate additions of its acid and base, will produce the same result.

Application. When clothes are spotted with acids or alkalies, neutral salts may be produced on the cloth, and the ill effects prevented, if attended to immediately. Thus if a black coat be spotted with sulphuric acid, any of the alkalies will extinguish the spot by neutralizing the acid.—Pearlash, or some other sub-carbonate, is preferable to the strong alkalies. The spot where the application is made must be washed immediately with pure water.

Remark. The infusion of red cabbage only is mentioned above as the test for acids and alkalies ; though blue violets, elder berries, and several other vegetable substances may be used.—These infusions are sure tests, excepting that water, charged with sulphuretted hydrogen, will change them to red, like acids.

Prop. 7. *Salts of potash are insoluble in pure alcohol.*

Illustration. Drop a hard lump of pearlash into good alcohol, and it will remain in the solid state any length of time.

Application. The common alcohol of the shops always contains considerable water. If perfectly dry pearlash is put into it, some of it will be dissolved by the water. The nearly pure supernatant alcohol may then be poured off for use.

Prop. 8. *Potash may be combined with chlorine, or oxymuriatic acid, and form the oxymuriate of potash.*

Illustration. Fill a two quart bladder with chlorine, or oxymuriatic acid gas. Fit to the stopcock of the bladder a small glass tube. Dissolve about an ounce and a half of pearlash in a pint of

water, and put it into a receiver. Immerse the end of the tube in the solution, and close the tubulature where it enters with beeswax. Lay a light weight upon the bladder, which will press it gently, and turn the stop so as to let out a very minute stream of the gas, so small that the whole shall not run out in less time than an hour or two. Let the receiver be almost air-tight, leaving only a hole a little larger than a pin in the wax by the side of the tube where it enters the receiver, for the carbonic acid to escape, which will be driven from its connexion with the pearlash. After the gas is all pressed out of the bladder, draw out the tube, close up the receiver, and place it in a cool dark cellar. After a day or two, crystals of oxymuriate of potash will be found deposited in the bottom of the receiver. Pour off the liquid, scrape out the crystals and drain them. They must then be dissolved in considerable hot water. Set it away to cool, and the crystals will be formed again, which may be drained, dried, and put up in a vial for use.

Application. This preparation will explain much of the doctrine of affinity, &c. to the operator; but so little of it can be performed while his class is present, that it is preferable to purchase this salt of those who manufacture it in the large way in Woulf's apparatus.

Prop. 9. *Oxymuriate of potash will communicate oxygen to some combustile substances by compression, sufficient to inflame them and to produce explosion.*

Illustration. Scatter some thin shavings of phosphorus over the bottom of a broad iron mortar. Sprinkle crystals of oxymuriate of potash among

them. Now, putting a leathern glove upon the hand, rub the iron pestle smartly around among the shavings of phosphorus, and a succession of explosions will be made, resembling the irregular discharges of militia musketry. It is probable that these explosions are caused by the sudden conversion of two solids into vapour. Oxygen is combined in the salt in the solid state. Phosphorus is also a solid. By being closely compressed, they instantly become phosphoric acid in a vaporous state.

Application. To the same principle all explosive powders owe their powers. Gunpowder is essentially composed of about 75 per cent of nitrate of potash, 15 per cent of charcoal, and 10 per cent of sulphur. These substances are finely pulverized separately, and then intimately mixed. The nitric acid of the nitrate of potash, on being inflamed, parts with so much of its oxygen as to be reduced to nitric oxid gas, and part of it to nitrogen gas. In doing this, oxygen is furnished to the charcoal sufficient to convert it into carbonic acid gas, and to the sulphur to convert it into sulphurous acid gas. These solid constituents of gunpowder, springing suddenly into the state of these four gases, expand their volume to such a vast extent, as to produce a violent concussion upon the atmosphere, and to impel a leaden ball, or other opposing body, with great velocity.

The same principle may be further illustrated by finely pulverizing and rubbing well together three parts of dried saltpetre, two of well dried pearlash, and one of sulphur. Melt the mixture in an iron ladle, with a degree of heat a little below the red heat of iron; and immediately after melt,

ing, the mixture will explode with violence. Here the three solid substances spring into several gases on the same principle as before explained.

PRINCIPLE 2. OF SODA.

Natural History and general Remarks.

Soda often constitutes a part of felspar. Therefore, like potash, it is contained in the oldest primitive rocks. It is found in animals and vegetables; but is not so abundant in vegetables as potash. It is very abundant in nature as the basis of common salt. For commerce it is mostly obtained by lixiviation, from the ashes of burned seaweeds, and sold under the name of barilla. It is sometimes called natron.

Soda has many properties in common with potash. It gives the alkaline test, is obtained pure in the same manner, unites with acids, animal matter, &c. But its affinity for the acids and animal matter, is more feeble; and it does not deliquesce by attracting vapour from the atmosphere. Combined with oils it forms hard soap, whereas potash always forms soft soap.

Prop. 1. Soda may be combined with muriatic acid, and form common table salt, muriate of soda.

Illustration. Put muriatic acid in a tumbler, diluted with about six times its measure of water. Drop in carbonate of soda till effervescence ceases. Proceed in all respects as directed in making salt-petre. Pass some of the solution among the class, and they will recognize the table salt.

Application. This salt is found so abundant in nature, that it is never produced in this way, excepting for the purpose of shewing its constitu-

ents. The ocean abounds in it, the western salt-springs, the mines of Poland, &c.

Prop. 2. Common salt may be decomposed by potash, and soda obtained.

Illustration. Dissolve an ounce of common salt (muriate of soda) in hot water. Add three fourths of an ounce of common potash. Keep the solution at a moderate heat until it is evaporated to dryness. Let it be evaporated on a broad plate that it may be very thinly spread over the bottom. Now expose it, in the open plate, to the atmosphere a day or two, and the muriate of potash will diliquesce, while the soda will assume the form of powder, or dust.

Application. Dissolve good soft soap by heating it in a clean tin basin with about twice its measure of rain or river water. Then put in about half a gill of fine common salt to a quart of this solution. The muriatic acid of the salt will unite with the potash of the soap, and leave the soda of the salt to unite with the oil of the soap. This latter compound after a little boiling, will become somewhat dense and float on the surface of the liquid. On draining out the liquid, which is chiefly muriate of potash, and drying the floating compound, the latter will be found to be common hard soap.

Thus soap-boilers make the common hard soap. The liquid muriate of potash they call waste-ley or dead-ley. The fine hard soap is made directly from the barilla or kelp, which is a rough sub-carbonate of soda made from the leached ashes of sea-weeds.

Prop. 3. Soda may be combined with sulphuric acid and form Glauber's salts.

Illustration. Put some sulphuric acid into a tumbler, diluted with six times as much water. Drop in carbonate of soda, until effervescence ceases. Now pass some of the liquid in wine glasses and the members of the class will recognize the nauseous taste of Glauber's salts. It may be crystallized by slow evaporation in the usual way.

Application. This salt is produced for the shops at the manufactories of muriatic acid. For the sulphuric acid which is poured upon common salt to disengage the muriatic acid, combines with the soda of the salt, and forms sulphate of soda. After purifying, it is sold to the druggists.

PRINCIPLE ? OF AMMONIA.

Natural History and general Remarks.

This substance is one of the compounds under Nitrogen. But it was referred to this place for a description of its properties, on account of its near relation to the fixed alkalies. This is usually called the volatile alkali. On account of its salts forming with mercury, under galvanic influence, a compound resembling the amalgams of mercury and other metals, Berzelius supposed it might be a metal, to be called ammonium. As ammonia is known to be a compound, and as it forms an amalgam with mercury, it goes far towards proving that potassium, sodium, &c. are compound bodies. The proof, however, is of that kind, called analogy. And there is some want of correct analogy; though it has a stronger bearing upon the subject, than that upon which the hypothesis of the basis of alumine is founded.

It seems to be proved by Gay Lussac, that it consists of 75 per cent of hydrogen and 25 per cent of nitrogen.

It is mostly found in the state of sal ammoniac (the muriate of ammonia) in Egypt. It is chiefly manufactured by the lixiviation process from the excrements of animals which feed on plants growing near salt water. It has been found near several extinct, or nearly extinct, volcanoes. The pure gaseous ammonia, and the various salts, are obtained from the muriate.

Prop. 1. *Ammonia is obtained in the state of gas from sal ammoniac by elective affinity.*

Illustration. Pulverize a table spoonful of sal ammoniac, (muriate of ammonia) and put the dry powder into a half pint retort. Put in with it about twice as much fine quicklime. Now mix them well by shaking the retort. Having luted on a pipe-bowl, with half an inch of the stem, upon the beak of the retort, as directed in obtaining muriatic acid gas and for the same reason; now immerse the beak in the mercurial trough, and apply the heat of a candle to the retort. The ammoniacal gas will immediately come over. Let it escape a little while, that the atmospheric air may be driven out. Now collect it as directed in collecting muriatic acid gas.

Application. Hartshorn vials may be prepared upon this principle. Put pulverized sal ammoniac and quicklime into a vial and cork it closely. Whenever the scent of the ammonia is wanted, shake the mixture before pulling out the cork. The same effect will be produced by rubbing dry quicklime upon the surface of a piece of sal ammoniac, and applying it to the nose. In all these

experiments, the muriatic acid of the muriate of ammonia elects the lime, and the ammonia is discharged; and ammonia when pure is in the state of gas.

Prop. 2. Ammonia extinguishes flame after a momentary enlargement of it, and destroys life when breathed.

Illustration. Immerse a short piece of a burning candle in a small cylindric glass of the gas. The blaze will be enlarged a little for an instant and then be extinguished. Put a mouse into it and it will soon expire.

Application. Though the action of this gas, by stimulating the olfactory nerves, revives a fainting patient; yet it will destroy life if respired several times. If oxymuriatic acid is inhaled by accident, let some ammoniacal gas be instantly inhaled after it, and it will correct its destructive effects. The two gases probably form an imperfect oxymuriate of ammonia in the lungs. That this effect is produced, I had an opportunity to demonstrate by most painful experience, while giving a course of lectures in the capitol, before the New-York state legislature.

Prop. 3. Ammonia in the state of gas, will unite with muriatic acid gas, and with carbonic acid gas; and with the former produce the solid muriate, and with the latter the solid carbonate of ammonia.

Illustration. Produce carbonic acid gas in the common way and ammoniacal gas as before directed. Let the two gases meet in the same globe receiver at different apertures, or at opposite ends of a cylinder or adopter, and the receiver will soon

be lined with carbonate of ammonia. If muriatic acid be substituted for carbonic, the muriate of ammonia will be produced. Or fill two small glass cylinders half full of ammoniacal gas over mercury. Pass muriatic acid gas into one from a vial which is small enough to turn under the cylinder, and carbonic acid gas into the other. Both cylinders will be lined with thin layers of salt, and the mercury will ascend to fill the vacancy. On passing the cylinders among the class with tasting rods, they will recognize the sal ammoniac (muriate of ammonia) in one, and the salts of hartshorn (carbonate of ammonia) in the other. Lest some of the class should not recollect the taste of these salts, it will be best to pass around specimens of each with the cylinders.

Application. These salts are not manufactured in this manner for the shops. The muriate of ammonia is produced in nature. The carbonate of ammonia is manufactured by heating chalk, (carbonate of lime) and muriate of ammonia together. A double decomposition takes place; carbonate of ammonia and muriate of lime are formed.

The experiments described in this illustration exhibit the reduction of gases to the solid state as clearly as any experiment of the laboratory.

Prop. 4. *Carbonate of ammonia may be manufactured by double elective affinity, with carbonate of lime and muriate of ammonia.*

Illustration. Put into a florence flask, or a retort, dry pulverized chalk (carbonate of lime) with half as much sal ammonia, (muriate of ammonia.) Heat the flask in a lead pot, and dry carbonate of ammonia will be sublimed and line

the neck. The heat must be considerable, sometimes requiring the retort to be coated with clay.

Application. Carbonate of ammonia is prepared in this manner for accurate experiments in the laboratory only. For commerce, it is prepared upon the same principle, but in a coarser manner.

Prop. 5. *Ammonia may be combined with nitric acid, and nitrate of ammonia be formed.*

Illustration. Put nitric acid into a tumbler diluted with about six times as much water. Drop into it coarsely pulverized carbonate of ammonia until effervescence ceases ; or until pieces of the carbonate will fall to the bottom without effervescence. A solution of nitrate of ammonia will then be formed. If it be required in crystals, evaporate it slowly, until a drop spread on cold glass is instantly crystallized. Then set it by to cool, and crystals will form on the top. Pour out the liquid part and evaporate it more, and so on as before directed. If the dry salt is required, evaporate it with a degree of heat a little below boiling, until the salt is dry, without removing it from the fire.

Application. This salt is chiefly employed for the purpose of procuring the nitrous oxid or exhilarating gas. It is much the best for that use, to dry the salt down without crystallizing. Or if it is first made in crystals, it ought to be melted and dried down in open plates, before it is used. But if it is dried with a degree of heat as high as the boiling point, considerable of the salt will be lost.

Prop. 6. *Ammonia is strongly absorbed by water, forming the liquid ammonia.*

Illustration. Pour from a vial a little cold water under a glass cylinder of ammoniacal gas standing over mercury. It will rapidly absorb the gas, and the mercury will ascend to fill the vacancy.

Put newly slacked lime into a tubulated retort which had been previously luted into a receiver, and set in a suitable lead pot. Put in about two-thirds as much pulverized muriate of ammonia. Now put in water, about six times the weight (call a pint a pound) of the muriate of ammonia. The muriatic acid will elect the lime as before observed, and the ammonia will be discharged; but it will immediately be arrested by the water, forming the *liquid ammonia*, called also *spirits of harts-horn* and *aqua ammonia*. But being combined with the newly formed muriate of lime and some lime water, it must be distilled over. Raise the heat moderately by applying the hand bellows to the coals in the lead pot; at the same time surround the receiver with snow or cold water. Continue the process until the liquid, condensed in the receiver, is equal in measure to about one third of the water put in.

Pure ammoniacal gas may be disengaged, without any water, by duly regulating the temperature, either during the above process or from the *aqua ammonia* of the shops.

Application. The first experiment proves, that as water absorbs ammonia, which is the basis of many impure gases that arise from putrid substances, falling rains cleanse the atmosphere by carrying such impure effluvia to the earth, where they serve to nourish vegetation. The last ex-

periment is an exhibition of the method of preparing the *aqua ammoniæ* of the shops.

Prop. 7. *Liquid ammonia will unite with sulphuretted hydrogen gas, and form the hydro-sulphuret of ammonia.*

Illustration. Let a stream of sulphuretted hydrogen gas pass into a vial of liquid ammonia. The best method is to put the ammonia into a broad mouthed vial, filling it about half full.—Turn the vial in an oblique position and extend the beak of the retort to the bottom of it. Wet tow may be wound about the neck of the retort where it enters the mouth of the vial to prevent the escape of the gas ; or if a little does escape it is immaterial, for the class ought to become sufficiently acquainted with this gas to be able to detect it by the smell. Now pour some of the liquid into a solution of copperas and another of blue vitriol.

Application. This is the most universal test for the metals known to chemists. It precipitates all metallic solutions with such different colours, when applied as a test, that, with collateral tests, almost any metal may be detected. For many metals it is a perfect test. It may be added that all the other alkalies will form hydro-sulphurets also. But ammonia forms the most delicate test and is generally used.

Prop. 8. *Ammonia may be decomposed and reduced to its constituent elements by heat. See Prop. 9. under Nitrogen.*

Illustration. Put quick lime and sal ammoniac into a florence flask, as before directed in producing ammonia. Fit a long tobacco pipe, (a small

iron tube will do) perfectly tight into the mouth of the flask. Pass the pipe through a lead pot, near its middle. Attach, so as to be tight, to the opposite end of the pipe, a glass or lead tube, bent down into a bowl of water. Raise the heat in the lead pot, until the pipe is red hot. Then commence heating the flask with a candle. As the ammoniacal gas is disengaged and passes through the red hot pipe, it will be decomposed, and its two constituent gases, hydrogen and nitrogen, will pass into the bowl of water, where it may be collected in small vials.

To test the received gases, pour them into a long slender tube. A long test glass will do. Let them stand about half an hour, and they will separate—the hydrogen rising to the top. Pour small portions at a time into a very small test glass and let down a minute burning taper into it. Do this several times. The nitrogen being at the bottom, the taper will be extinguished at first. At last the hydrogen will show itself by burning.

Application. This experiment gives a very satisfactory illustration of the essential changes which may be produced by chemical combination; as the ammoniacal gas differs so widely in its properties from hydrogen or nitrogen.

PRINCIPLE 3. OF LIME.

Natural History and general Remarks.

Lime is very abundant. It forms the basis of all lime rocks which are combined with carbonic acid, whether primitive, transition or secondary; from those which receive a polish called marble, to the roughest of the common lime stone. It is

the basis of chalk, corol rocks and shells. Combined with sulphuric acid, it forms the vast plaster beds of Nova-Scotia and our western districts. Combined with phosphoric acid, it forms the bones of animals.

When carbonate of lime is heated about as high as the white heat of iron, the carbonic acid is converted into a gas and passes off. This process is conducted in large kilns, where quicklime is manufactured.

Prop. 1. Pure lime has a strong affinity for water.

Illustration. Put a wine-glass full of newly slacked lime into a quart decanter, and fill it with water. After shaking it about a minute, let it stand fifteen or twenty hours to settle. Now pour off the colourless liquid into large vials for use.

Pour some of the lime water into a wine glass and test it by a few drops of the infusion of red cabbage. It will become green, which is the alkaline test ; proving that the water, though limpid, is chemically combined with lime.

Application. Stone lime, as it is called, during the process of slacking, attracts water so powerfully as to convert some of it into a solid, while other portions are converted into vapour, by the caloric disengaged from the solidified portion. The same slacked lime continues to attract and to solidify water for a long time when in the state of mortar. It is said that mortar grows stronger for centuries by the slow additions of water and carbonic acid.

The strong affinity of quicklime for water renders it an excellent drying material. An enclosed

portion of atmospheric air or of any other gas may be dried by standing over unslacked lime. Col. Gibbs greatly improved the strength of gun-powder by mixing it with quicklime, and thereby effectually drying it. Vid. Amer. Jour. Science, vol. 1, p. 87.

Prop. 2. *Lime water strongly absorbs sulphuretted hydrogen gas, and forms the hydro-sulphuret of lime.*

Illustration. Pass sulphuretted hydrogen gas into lime water, as directed with ammonia, and the hydro-sulphuret will be formed.

Application. This forms a good test for metals, but not so delicate as the hydro-sulphuret of ammonia. This experiment, showing the affinity of lime for sulphuretted hydrogen gas, demonstrates its utility in cleansing putrid sinks, &c. For sulphuretted hydrogen being the essential part of most of the nauseous effluvia, if absorbed by lime the most disagreeable nuisance will be removed. For the same reason lime water is useful in cleansing offensive ulcers, &c.

Prop. 3. *Most salts of lime have a strong attraction for water.*

Illustration. The salt of lime called gypsum, (sulphate of lime) becomes a powerful cement by its attraction for water, after its native portion of water has been disengaged by heat. Pulverize a portion of gypsum and heat it in a crucible, covered by the next smaller crucible in the nest, inverted, until it is to a white heat. Cork it close in a bottle to exclude moisture. Wet up a portion of this powder to the state of a paste, and in about five minutes it will become solid. Bricks, stones, &c. may be joined by it very firmly.

Application. On this principle a cement is made in a large way for busts, for the manufacture of buhr millstones, for hard-finished walls, &c. If it hardens too quick, a weak solution of animal glue added to the paste, will postpone the hardening.

Prop. 4. *Lime will combine with carbonic acid, and form carbonate of lime.*

Illustration. Set a tumbler of carbonic acid gas on the table, covered with a piece of pasteboard. After filling a low small glass cup with limpid lime-water, remove the pasteboard and let it down into the tumbler. Now stir it two or three minutes with a rod, and it will absorb so much carbonic acid that part of the lime will be carbonated, and become milky. Now take out the cup and set it by a few minutes to settle. On carefully pouring off the liquid, fine carbonate of lime, which may properly be called fine chalk, will be left. This may be tested by its effervescing on pouring upon it a little diluted sulphuric acid.

Application. Thus we see from this experiment, that carbonic acid may be driven from limestone by heat, rendering it pure quicklime; and it may be absorbed from the atmosphere, re-united, and form the carbonate again. Thus lime mortar in walls becomes solid like marble, on exposure to air. On this principle a bowl of lime-water set in a room and occasionally agitated, would absorb the carbonic acid gas when a large quantity had been produced by the breaths of a crowd.

Prop. 5. *Carbonate of lime is dissolved in carbonated water, and will be deposited when the carbonic acid is abstracted.*

Illustration. Prepare some carbonate of lime as directed under Prop. 4, for native carbonate cannot be used without occupying too much time for a lecture. Drop a few grains into a florence flask or half-pint matrass or bolt-head, half filled with carbonated water. It will give a cloudy appearance to the water at first; but it will be entirely dissolved and the water will become limpid again in a few seconds. Now set the flask into the lead pot, and boil the water four or five minutes. Take it out, wipe it clean and set it by to cool. After it is cool the fine carbonate of lime will appear again in the bottom of the flask. For the carbonic acid being driven out of the water by heat, the carbonate of lime is deposited.

Application. This experiment explains the manner in which the calcareous tufa, called the high rock at Saratoga, is formed, and numerous other similar deposits. The carbonate of lime is brought along chemically combined with the carbonated water, until it comes out to be exposed to the atmosphere. Then a part of the carbonic acid escapes, and a part of the lime is deposited. Probably the numerous deposits of this mineral were made by carbonated waters which have ceased to flow for ages. The most remarkable locality within my knowledge, is at the head of Otsuago creek, ten miles south of the canal at Fort-Plain. There is another on the Erie canal, a few miles east of Salina.

Remarks. A vacuum almost as perfect as can be obtained by the air-pump, may be produced by lime-water and carbonic acid gas. Fill a cologne bottle, decanter, bolt-head, or other suitable vessel, with carbonic acid gas. Introduce very cold

well-prepared lime water to the bottom of the vessel through a tube, sufficient to equal one-eighth of the measure of the gas. It must be introduced without any agitation. Cork the vessel perfectly tight. Now shake it violently. The lime water will absorb the gas and produce a vacuum. If the vessel is shaken, the water will strike against the sides with a clinking sound. But if the temperature of the water is raised a very little, it will fill the vessel with vapour, as in other cases when atmospheric pressure is removed.

Prop. 6. *Lime has a strong affinity for oily substances.*

Illustration. Pour olive oil into a wine-glass of lime water, and the white liquid soap will be formed, by the union of the oil and lime, which is used as a remedy for burns.

Application. Lime is used in connection with potash, &c. by the soap boilers. It absorbs oils feebly in the state of a carbonate. The leaves of a book are often spotted with candle grease, lamp oil, &c. These spots may be totally removed by finely pulverized chalk or marble. Let the leaf of a book be placed between two pieces of white paper, with pulverized chalk interposed on both sides. Then set a common smoothing iron upon it, sufficiently heated to melt the grease. As soon as it is melted, the chalk will absorb it.

Prop. 7. *Lime, when mixed with silex or alumine, renders the mixture fusible.*

Illustration. Put a little potter's clay paste into a crucible, and heat it in the forge as high as the white heat of iron. Now pour it out upon a brick on the table, and the class will see that it is not

melted. Mix some of the same kind of clay intimately with about an equal quantity of pulverized marble or chalk, and heat it again as hot as before. Pour it out, and the whole mass will spread upon the brick in the state of melted cinder.

Application. On this principle potters reject all clay which contains lime. About Albany and other places along the banks of the Hudson, there is an abundance of the finest clay; but it contains about fifteen per cent of carbonate of lime. This would be sufficient to cause a kiln of potter's ware to melt, and of course cannot be used. The carbonate of lime can always be detected by pouring on a few drops of diluted muriatic acid. Ever so small a proportion of the lime will cause an effervescence, and prove the mass to be clay-marl, unfit for pottery.

Prop. 8. *Lime will combine with muriatic acid and form muriate of lime; which salt in solution will change to solid gypsum on adding sulphuric acid.*

Illustration. Pour diluted muriatic acid into a tumbler, consisting of about three times as much water as acid. Drop in pulverized chalk or marble until effervescence ceases, and muriate of lime in solution will be formed. Now pour a spoonful into a wine-glass, and pour into it sulphuric acid; solid gypsum, sulphate of lime, will be instantly formed if it is not stirred.

Application. Most of the hard waters, as they are called, contain muriate of lime in solution. From this experiment it appears, that muriate of lime may be decomposed, and other salts of lime formed which are insoluble. Some of these salts

adhere to the bottoms and sides of vessels, as tea-kettles, &c.

Prop. 9. *Lime will combine with oxymuriatic acid and form the oxymuriate of lime.*

Illustration. Let a stream of oxymuriatic acid pass into water, in which finely pulverized and recently slacked lime is suspended by continual agitation. In the large way, a dry powder of newly slacked lime is agitated in a strong cask, and the gas passed into the cask, which is absorbed by the lime. Others, however, prefer passing the gas into hogsheads of water, in which the lime is suspended by agitation. For an experiment, it may be pressed from a bladder, as directed in making oxymuriate of potash. But the bladder may be held in the hands and the receiver shaken continually.

Application. This is the bleaching salt, now used at the great factories. The manner of applying the salt is described in treatises on bleaching. It would be too long an article to introduce here. Students are referred to the factories.

PRINCIPLE 4. OF BARYTES.

Natural History and general Remarks.

Barytes possesses many properties in common with lime. It is found in the United States in the state of a sulphate, in considerable quantities. The most extensive locality perhaps yet discovered in the world, is that in Carlisle, Schoharie county, New-York. This is a fibrous variety, but differs widely in its external characters from the fibrous varieties of Europe. It is called Schoharite, from its local situation, being near the

western bank of the Schoharie kill. This variety is an excellent flux for brazing, &c. Perhaps every variety is equally good ; but this has been proved to be so by abundant trials. All the salts of barytes, excepting the sulphate, are most deadly poisons.

Prop. 1. Carbonate of barytes may be obtained from the native sulphate, by exchanging acids with pearlash, the sub-carbonate of potash.

Illustration. Put into a gallipot or florence flask, pulverized sulphate of barytes with about three times as much pearlash, and apply heat sufficient first to melt the pearlash and then to boil the mixture for about three hours. Water may be added from time to time. Now put in considerable water so as to make a very diluted solution. Let it stand awhile, and the carbonate of barytes, which is produced by this double decomposition, will settle to the bottom, and the sulphate of potash will remain in solution. Pour off the liquid and put in water again, and thus wash it two or three times, and it will be ready for use.

Application. Having obtained carbonate of barytes, it is in a situation to be readily brought into any other state. As it has a stronger affinity for nitric, muriatic or sulphuric acid, than it has for the carbonic, either of those salts may be formed in the common way. Or if it be kept at a white heat in a crucible about half an hour, the pure barytes will be obtained. This will combine with water like lime, and form the barytic water, an excellent test.

Prop. 2. Barytes will combine with muriatic or nitric acid, and form a test for the presence of sulphuric acid.

Illustration. Put muriatic or nitric acid into a tumbler diluted with about six times as much water. Drop in the carbonate of barytes, until effervescence ceases.

Application. This forms a perfect test for sulphuric acid in any state of combination. But it is a most deadly poison.

PRINCIPLE 5. OF STRONTIAN.

Natural History and general Remarks.

Strontian has lately been found by Professor Douglass and W. A. Bird, in great abundance on an island in Lake Erie, in the state of a sulphate. It was passed from hand to hand among mineralogists in New-York as crystallized sulphate of barytes for a considerable time. I first analyzed it before the members of the Troy Lyceum, and there demonstrated it to be sulphate of strontian. I have since examined its geological relations. It is found only in a kind of swine-stone or geodiferous limestone. It is found in geodes in this rock at Rochester, Lockport, Niagara Falls, on most of the islands in Lake Erie, &c.

It possesses many properties in common with barytes, and its salts are obtained as directed under barytes ; but none of its salts are poisonous.

Prop. 1. *The salts of strontian may be distinguished from those of barytes by the colour of its flame when burned with alcohol.*

Illustration. Dissolve a little of the muriate or nitrate of barytes and of strontian in separate portions of alcohol. Drop a little of each into the burning wicks of separate candles. The barytic

salt will burn with a yellow, the strontian with a deep red, flame. The solutions may be held in the blaze in silver tea-spoons, and they will burn more elegantly.

Application. These two heavy minerals greatly resemble each other. They are both used for tests, and probably may both be useful as fluxes. They will both combine with sulphuretted hydrogen, forming hydro-sulphurets; and by heating with sulphur, form sulphurets like all other alkalies.

PRINCIPLE 6. OF MAGNESIA.

Natural History and general Remarks.

Magnesia forms one of the constituents of the soapstone or talcose rocks, of asbestos, and some other minerals. It is found pure, or merely combined with water, in connexion with soapstone and serpentine rocks, at Hoboken, opposite to New-York. It is found in the state of a carbonate in the same range of soapstone or talcose rock on Staten Island. It is found in the state of an efflorescent sulphate, (called Epsom salts) in great quantities six miles north of Troy, on the east bank of the Hudson; also in the same situation at Coeymans, on the west side of the Hudson. Near the latter place is a spring highly charged with it. But magnesia is generally obtained from sea-water, after it is separated from the common salt. It exists in the state of a muriate and sulphate in sea-water, from which it is obtained by mixing with it a solution of common pearlash. A double decomposition takes place; and while the sulphate of potash remains in solution, the car-

bonate of magnesia falls down. The carbonate of magnesia thus obtained, is the white magnesia of the shops.

Prop. 1. *The carbonic acid may be driven from its connexion with the magnesia of the shops by caloric.*

Illustration. Drop diluted sulphuric acid upon carbonate of magnesia of the shops and it will effervesce violently ; that is, a bubbling will be caused by the escape of carbonic acid in the state of gas. Put a little of the same carbonate of magnesia into a crucible and keep it about the white heat of iron fifteen minutes. Now, after it cools, drop on it diluted sulphuric acid and it will scarcely effervesce, because the carbonic acid is driven out. If a little of it be dissolved with water it will give the alkaline test with red cabbage much stronger than before heating. I have never succeeded in driving off all the carbonic acid by heat, so that no effervescence can be produced by the application of sulphuric acid.

Application. This is called the calcined magnesia ; and is considered as a more efficient remedy in some diseases than the carbonate.

Prop. 2. *Magnesia will combine with sulphuric acid and form the Epsom salts.*

Illustration. Put sulphuric acid into a tumbler, diluted with about six times as much water. Drop in carbonate of magnesia until effervescence ceases. This will form Epsom salts in solution. Pass some of it around, and the class will recognize the bitter taste of the Epsom salts.

Application. This salt is so abundant in nature, that it is never prepared in this way, except-

ing by way of experiment, or when a practising physician happens to be in want of this article of *materia medica*.

PRINCIPLE 7. OF LITHIA.

Natural History and general Remarks.

Lithia is an alkali found in a rare mineral, called petalite, by Arfvedson, Berzelius' assistant, in the proportion of 5 or 6 per cent, with about 79 of silex and 16 of alumine. It approaches soda in its characters; as it forms a salt with muriatic acid resembling common salt in taste and in its crystalline form. It dissolves very slowly in water, giving off heat like lime when slacking. It is almost as caustic to the taste as potash.

SECTION 2. EARTHS WHICH ARE NOT ALKALINE.

General Remarks.

It is conjectured from analogy, that these earths consist of peculiar bases united to oxygen. These imaginary bases may be called metalloids also. Some chemists, however, have placed silex among oxidable substances not metallic, and denominate it silicon. Gorham has followed that arrangement, but Brande has not.

PRINCIPLE 8. OF SILEX.

Natural History and general Remarks.

Silex is the most abundant substance known to us. It constitutes the largest proportion of most

rocks and soils. No rock stratum, excepting some lime rocks, is destitute of silex. Quartz crystals are almost pure silex. Most gems, excepting the diamond, the pearl, and the sapphire family, are chiefly composed of silex. The common gun-flint, the carnelion, and the quartz crystal, are of very common use in the arts.

Prop. 1. *Silex may be obtained pure from its earthy compounds, by combining it with an alkali and then separating the alkali with an acid.*

Illustration. Previous to the commencement of the lecture, heat a gun-flint red hot and throw it into cold water in order to render it brittle. Pulverize it very fine and mix the powder with about five times its bulk of pearlash, melt the mixture and keep it in the state of fusion fifteen minutes. Now dissolve it in two or three times its bulk of water. At the lecture pour in diluted sulphuric or muriatic acid, a little at a time, as long as it continues to cause a precipitation. After it stands a little while to settle, pour off the liquid part, and wash or rinse the precipitate in hot water several times until the water poured off is tasteless. This powder is pure silex.

Application. This substance is the basis, or rather the principal ingredient in gun-flints, rock crystal, carnelion, &c. It forms much the largest proportion of soils and rocks. It is soluble in fluoric acid, as shewn under fluorine, but in no other acid. Heat rock crystal red hot and plunge it into water, and then pulverize it, and it will be almost pure silex; for crystallized quartz consists almost entirely of pure silex and the water of crystallization.

From the experiment described under this illus-

tration, it appears, that silex is readily dissolved when heated with potash. On this principle glass is manufactured. A due proportion of potash and quartzose sand are heated together and fused into liquid glass. This substance is then blown, while it adheres to the end of a tube, into the various forms required.

Prop. 2. Glass sometimes contains the oxid of a metal, which may be tarnished by hydro-sulphuret of ammonia.

Illustration. Pour some hydro-sulphuret of ammonia into any vessel of flint glass, (which always contains red lead) and it will become dark coloured and cloudy within, after standing one hour. At the same time pour some into a vessel of crown glass, bottle glass, or on common window glass, and it will not be tarnished. But the flint glass vessel ought to be new; for if it has been used, the lead which is near the inner surface of the glass will probably be worn off or dissolved, so that none will be left to receive the tarnish.

Application. False gems made in imitation of true ones are always coloured with the oxid of a metal. Oxid of cobalt colours a glass gem smalt blue—black oxid of manganese, violet—oxid of chrome, emerald green, &c. If any such imitation gem be put into the hydro-sulphuret of ammonia, it will soon become tarnished.

The most convenient method for detecting frauds of artists, practised with false gems, is the following: Let gems be divided into four classes, according to their hardness. 1. Diamonds. 2. The sapphire class. 3. The rock crystal class. 4. Glass imitation gems. When a gem is to be examined, look out a smooth face upon it with a

magnifying glass. Apply to that face a point or angle of a quartz crystal and attempt to scratch it. If any scratch is made, attempt to scratch the quartz with the gem. If the quartz cannot be scratched by it, it is glass; if it can, it is quartz. Minerals of equal hardness will scratch each other; therefore quartz will scratch quartz, &c. If it cannot be scratched with a quartz crystal, it may be considered as belonging either to the sapphire or to the diamond class. In this class are included oriental ruby, oriental amethyst, oriental topaz, corundums, emery, &c. Select a large smooth grain of unground emery, and apply it to the face of the gem as before directed. If it can be scratched with emery, but with great difficulty, and not by the quartz crystal, it may be considered as belonging to the sapphire class. But if it cannot possibly be scratched with emery, after the most careful trials, with severe pressure, it is a diamond.

PRINCIPLE 9. ALUMINE.

Natural History and general Remarks.

Alumine is the most generally known as the basis of clay; though common clay soil contains more silex than alumine. It constitutes the chief of the basis of alum. It is a constituent of every rock stratum, excepting some lime rocks. It has been found in a pure uncombined state in but one locality. Dr. E. Emmons discovered it in the summer of 1819, in an iron mine in Richmond, Mass. He demonstrated it to be a new mineral by the Wernerian external characters, without a chemical analysis. Professor Dewey was the first who

proved that it consisted of pure alumine and water.

Clay beds are generally divided into the marly clay (according to Pierce,) and the plastic clay. The clay-beds of the United States are chiefly of the marly kind, and contain from ten to twenty per cent of carbonate of lime. These beds are unfit for potter bakers' stone ware; because such a compound fuses before it is sufficiently baked. Plastic clay, which is often destitute of any carbonate of lime, is of great value in the arts. It is not only essential to the potter baker, but is necessary for the construction of all furnaces, where a high heat is required.

The celebrated Wedgewood's ware depends, for its peculiarity, on the clay being burned and pulverized previous to its final manufacture.

Prop. 1. *The alum of commerce consists of alumine combined with sulphuric acid, and a little potash; from this salt the alumine may be precipitated by ammonia.*

Illustration. Dissolve common alum in water before the lecture hour. In time of lecture, pour into it liquid ammonia and a dense precipitate will appear. Now let it settle several hours and pour off the liquid, and wash this precipitate several times in water. This will be the pure, or nearly pure, alumine.

Application. This is the basis of clay, used in the laboratory only.

Prop. 2. *Alumine mixed with silex, forms the chief part of soils; which mixture when moistened with water, will absorb ammonia, carbonic acid gas, carburetted hydrogen gas, and all other gases which are nutritious to growing vegetables.*

Illustration. Prepare opodeldoc vials of these gases over mercury, and pass into them separately balls of moistened earth. Some portion of each gas will be absorbed, with more or less rapidity. Some of them must stand several hours.

Application. From this experiment it appears, that the more frequently the moist earth is presented to the atmosphere by frequent hoeing, harrowing or ploughing, the more of the nutritious gases will be absorbed from it. This absorption, while it enriches the soil, purifies the air and renders it better fitted for respiration. This experiment explains the cause of the superior fertility of soils in the vicinity of large towns, compared with similar soils in different situations. The various impurities generated in large towns, the vast quantities of carbonic acid gas given off in respiration, the carburetted hydrogen and carbonic acid gases from a multitude of chimnies, &c. so highly charge the atmosphere with gases which are favourable to the growth of vegetables, that the very winds become the farmers' manure carters.

Prop. 3. *Acetate of alumine is made by double elective affinity, with alum and sugar of lead.*

Illustration. Dissolve equal parts of alum and sugar of lead in water in separate wine-glasses, before lecture hour. At the lecture, mix these solutions. The acids exchange bases; and the sulphate of lead falls down, while the acetate of alumine remains over it in a liquid state. This liquid may be poured off for use.

Application. Though by this process we do not obtain a perfectly pure salt, Dr. Cooper says that it is manufactured in this way by the calico

printers. It is an important mordant, much used in dying.

Prop. 4. *Alumine attracts water powerfully, by which its bulk is much enlarged ; and its bulk becomes greatly diminished by forcing out the water with caloric.*

Illustration. Make small clay cakes and dry them in the sun. Now bring them before the class, and mark their dimensions upon a board. Heat them in a crucible to the white heat of iron. Cool them and apply them to the measure, and they will be found to be greatly diminished in size.

Application. On this principle Wedgewood constructed his pyrometer. Nail down two thirty inch rulers on a board, half an inch apart at one end and an inch apart at the other. Graduate one of the rulers with marked degrees. If the sun-dried cakes of clay would just enter the large end, after heating they would enter considerable farther. The distance to which they would enter would indicate the degree of heat which had been applied to the crucible containing the clay cake and the metal, or other substance to be fused.

On this principle some bricks burned at a kiln are smaller than others, though all were made in the same mould.

Prop. 5. *Alumine has a strong affinity for the alkalies, whether they are simple or in the state of salts.*

Illustration. Lay a sun-dried plastic or refractory clay cake obliquely across a crucible, of such a length as to go entirely into the crucible, but not let it reach the bottom. Heat the crucible

until the clay cake is at a white heat. Then throw a little common salt, muriate of soda, into the crucible, and continue to raise the heat. On taking out the clay cake its surface will be found covered with a glazing, made up of the soda and alumine fused together.

Dip a dried cake into mortar, sufficiently diluted with water to become a free liquid, which is made of marly clay. Then heat it as before, and it will become glazed. This is caused by the fusion of the marly clay upon the surface of the refractory clay cake.

Application. The affinity between lime and alumine has an useful application in forming plastering for walls, &c. The experiment of glazing the clay cake is an exhibition of the process adopted by potter bakers for glazing their ware, by throwing salt into the kilns when the ware is burning.

PRINCIPLE 10. OF GLYCINE.

Natural History and general Remarks.

Glycine is found in emerald or beryl. The beryl of Haddam, in Connecticut, yields about fourteen per cent of glycine. It is capable of becoming a slightly adhesive paste in water. It is dissolved in the alkalies. All the salts, of which it forms the basis, are sweetish and somewhat astringent. Not used in the arts.

PRINCIPLE 11. OF ZIRCON.

Natural History and general Remarks.

Zircon is found in granite and in gneiss, in the

form of four-sided prisms. It is found in several localities in the United States. The crystals contain about twenty-five to thirty-five per cent of silex and a little oxid of iron. The pure zircon is insoluble in water, but unites with all the acids. Soluble in no pure alkali, but is soluble in their carbonates. Not used in the arts.

PRINCIPLE 12. OF YTTRIA.

Natural History and general Remarks.

Yttria is found in gadolinite from Sweden. It is combined with silex, oxid of cerium and oxid of iron. When pure it is insoluble in water, soluble in most acids, also in the carbonate of ammonia. Some chemists consider it as a metal. It is a doubtful substance, and not used in the arts.

PRINCIPLE 13. OF THORINA.

Natural History and general Remarks.

Thorina was lately discovered by Berzelius, in the gadolinite of Sweden. It resembles zircon. Its salts are astringent but not sweet. It is extremely rare and not used in the arts.

CLASS V. METALS.

General Remarks.

The specific gravity of all pure metals is above five. They all reflect light brilliantly, which reflection is called the metallic lustre. Most of them are found in the earth combined with oxygen or sulphur. All are capable of becoming sulphurets by heating with sulphur, as directed in preparing sulphuretted hydrogen gas. Metals may be combined or alloyed together, in which state their fusibility is increased.

Many experiments upon metals require so much time that they cannot be commenced and completed in the course of a lecture, or of one meeting of the class. Others are of a difficult or rather dangerous nature. These may be passed over in a short course of lectures, after giving very particular explanations of their principles; and shewing, as well as can be done conveniently without actually performing the experiments, the necessary manipulations. These are distinguished by an asterisk (*) prefixed to the illustration.

Prop. 1. All metals must be in the state of oxids before they can combine with acids and form salts.

Illustration. 1. Put a drop of mercury into a wine-glass and pour muriatic acid upon it. Muriatic acid cannot be decomposed by any metal, and mercury cannot decompose the water which is combined with the muriatic acid. Consequently the mercury will not be oxidated, and of course cannot become the base of a salt in this experiment.

2. Put a drop of mercury into a wine-glass and pour nitric acid upon it. Though the water, which is combined with the nitric acid, cannot be decomposed by mercury, nitric acid can. Consequently the mercury will be oxidated in successive atoms by successive atoms of nitric acid; which will be reduced thereby to nitrous acid, and rise up in a deep orange gas, as described under nitrogen. As fast as the successive atoms of mercury are oxidated, they unite with the nearest atoms of undecomposed nitric acid, and nitrate of mercury is formed.

3. Pour muriatic acid upon nitrate of mercury, and the acid will take up the base of the nitrate; because the mercury, having been oxidated by decomposing the nitric acid, readily elects the muriatic acid, for which it has the stronger affinity.

4. Put a small quantity of iron filings into a wine-glass, and pour muriatic acid upon it.— Though the muriatic acid cannot be decomposed by the iron nor by any other metal, as before observed; the water which is combined with the muriatic acid is readily decomposed by the iron. That the iron is oxidated by the oxygen of the water, is manifest from the disengagement of hydrogen gas which arises out of the wine-glass. The iron being thus oxidated, immediately unites with the muriatic acid and forms muriate of iron.

Remark. In the second and fourth experiments considerable effervescence appears in the wine-glass. In the second, it is caused by the escape of the nitrous acid gas, (or rather nitric oxid which becomes nitrous acid when it comes in contact with atmospheric air,) and in the fourth by the escape of hydrogen.

Application. Metals may be thus oxidated by the decomposition of acids or of water, or they may have been previously oxidated by some other process. In some cases a metal is first oxidated by an acid which it can decompose, and then united to a different one by double decomposition. For example, in preparing muriate of mercury of the shops, the mercury is first combined with sulphuric acid, because it will decompose that acid and become oxidated. Then its oxid is combined with muriatic acid, by heating the sulphate of mercury with the muriate of soda. This process of double decomposition will be particularly explained under mercury.

Prop. 2. *Several of the metals may be burned with a brilliant flame, in a current of oxygen gas.*

Illustration. Make a hole in the side of a large piece of charcoal, and put into the hole some iron filings, iron wire, zinc shavings, lead shavings, &c. Having filled a gas-holder with oxygen, provided with a tin or lead tube, terminating in a pipe-stem, as described in the introduction; hold the charcoal in a suitable position for receiving the current of oxygen upon the metals. Let an assistant hold the flame of a candle between the metals and the pipe, until the current of oxygen drives the flame into the coal. Then remove the candle and continue the current of oxygen, enlarging or contracting it at pleasure by turning the stop. The metals will burn very brilliantly, each exhibiting its own peculiar flame.

Application. This experiment demonstrates the combustibility of metals; and shows the necessity of adding to the words *acidifiable substances* in the title of the third class, the words *not me-*

tatic. For all combustible substances are capable of uniting with oxygen, and do unite with it during the process of combustion.

Prop. 3. *A very intense heat for burning metals may be produced by a current of oxygen and hydrogen gases combined.*

Illustration. Fit the ends of two tobacco pipe-stems together at right angles, by filing them with a small three cornered file in the following manner. File the hydrogen pipe flat on one side at the end, and file a groove across the end at right angles with the flat side. File the oxygen pipe at the end so as to make a shoulder to fit against the flat side of the hydrogen pipe, and file it so deep as to leave but half of the hollow of the pipe-stem; which, when the pipes are put together, will exactly coincide with the groove across the end of the hydrogen pipe. Now bore two holes in a slip of a pine board, in a direction to fit in the pipes firmly, with their ends meeting in a joint at right angles as before described; but they ought to meet 3 or 4 inches from the board. Fasten the board in an upright position to support the pipes steadily. Having filled one gas-holder with oxygen and another with hydrogen, with stop-cocks fitted in them as usual, attach two leaden tubes to the stop-cocks at one end, and to the pipe-stems at the other, so as to conduct the proper gas to its respective pipe. Now turn the stop of the hydrogen gas-holder and let out a very small stream and inflame it with a candle. Then turn the stop of the oxygen gas-holder, and let out a stream of oxygen rather larger than that of the hydrogen. A small faint blaze will be produced, but its heat will be very intense. Having previously provided the

different metals intended to be burned, now apply them. Small rods of iron, lead, copper, &c. and gold and silver leaf, will burn like tinder. A very thin file with a long wooden handle, will burn beautifully.

Application. On this principle minerals can be burned or fused which resist the strongest furnace heat.—This is called the oxi-hydrogen blow-pipe of Hare & Silliman.

Prop. 4. *Metals, when cold as it is possible to make them, give off caloric if their particles are made to approach each other.*

Illustration. Anneal a common nail-rod, and when cold, hammer a small portion of it very briskly upon an anvil, and it will become hot—if continued until it is drawn out very small, it will become red hot. The same rod, or a large annealed wire, will become hot by frequent bending back and forward.

Application. A fire may be kindled by violently compressing a metal, while in contact with any highly combustible substance.

Prop. 5. *Letters may be etched upon metals by converting the surface, where the strokes are to be etched, or the interstices between them, into oxids, or salts.*

Illustration. Dip a clean copper cent into melted white wax. On taking it out the wax will immediately harden upon it. Mark out the form of a letter or figure upon it. Then immerse the cent in the nitric acid, and let it remain fifteen minutes. Now take it out, scrape off the wax, and wash the whole clean. The letter will be etched upon the cent.

Application. On this principle the etching upon razors, sword blades, &c. is performed. But the artists have various methods for preparing compositions for applying to the metals before the acid is applied. They generally make use of something for writing the letters, which will flow from the pen like ink. Then they surround the whole space to be acted upon, by an edging to confine the acid, and pour on the acid instead of immersing the metal in it. This is called etching in basso-relievo.

Prop. 6. Metallic salts may be decomposed very readily by alkalies and alkaline salts, unless the acid is metallic.

Illustration. Dissolve in separate wine-glasses a little copperas, blue vitriol, white vitriol, and sugar of lead. Pour into each a small quantity of the solution of either potash, soda, or ammonia, and the metallic oxid of the salt will be precipitated, and an alkaline salt formed in each glass. But if chromate of potash be dissolved, and sugar of lead in solution be poured into it, chromate of lead will be produced. For the acid, being metallic, has the strongest affinity for metallic oxids.

Application. This principle is of much use in the manufacture of articles used in medicine and the arts, as will appear by attending to the daily business of every laboratory.

SECTION 1. METALS WHICH ABSORB OXYGEN WITH SUCH FORCE AS TO DECOMPOSE WATER, WHEN HEATED TO REDNESS.

Illustration. The distinctive character of this section may be illustrated by heating an iron rod to a high red heat and plunging it into a narrow

mouthed tin cup of water. The smell of hydrogen will immediately be perceptible at the mouth of the cup, proving the decomposition of water; and on taking out the rod it will be covered with scales of protoxid of iron.

PRINCIPLE 1. IRON.

Natural History and general Remarks.

Iron is distinguished in the arts by three general kinds: *Cast iron*, *wrought iron* and *steel*. Cast iron contains a proportion of carbon, and is of a brittle granulated structure. By melting cast iron and stirring it while in fusion, part of the carbon is burned out. Then by hammering or rolling, it becomes almost pure, fibrous and tough, and is then called wrought iron. After it is brought to the state of wrought iron, it may be converted into steel by heating in a confined place in contact with charcoal, with which it combines. It will then become hard on heating and plunging into cold water, and is more fusible.

Besides the cast iron and steel, iron enters into another state of combination with carbon, forming the plumbago or black lead, as it is called. This is considered as the true carburet of iron, consisting of 95 per cent of carbon with 5 of iron, according to Allen and Pepys.

Oxids of iron form the basis of most colours in minerals and vegetables. Gorham quotes from Haüy this elegant and appropriate expression—"when nature takes the pencil, iron is the colouring she always uses."

Iron is rarely found pure. It is most generally found in the state of an oxid or of a sulphuret; though it is found in the state of a carbonate, sul-

phate, phosphate, arseniate, chromate, muriate, &c. In the oldest primitive rocks it is generally found in the state of a protoxid, and is considerably magnetic. In secondary rocks and in alluvial deposits, it is often found in the state of a peroxid, and compounded with clay: It is then called argillaceous iron ore. In the more recent primitive formations, it is found in a mixed state, consisting of the protoxid and peroxid, in various proportions. It is then called hematitic oxid of iron.

Iron is the most abundant and the most useful of all the metals.

Prop. 1. Steel may be distinguished from iron by the action of an acid upon its carbon.

Illustration. Let fall one drop of nitric acid upon a piece of polished iron, and another upon a piece of polished steel. The acid on the iron will be limpid or whitish, that on the steel will become dark brown or black.

Application. It is often very convenient to have a more ready method for distinguishing between iron and steel than the usual method of trying its hardening quality. It is not necessary to polish the iron or steel to make the trial. If a small spot on a coarse bar of iron or steel be filed bright it will be sufficient.

Prop. 2. Iron becomes oxidated on exposure to air and water; and the red oxid, or iron rust, thus made, always contains some carbonate of iron in combination.

Illustration. Collect some red iron rust and pour muriatic acid upon it, and carbonic acid will escape. Or heat it in a gun-barrel, as in obtain-

ing oxygen from manganese, and carbonic acid may be collected.

Application. Iron rust, prepared by exposing very fine iron filings to water and air, is often used in medicine as a tonic. But it is a mistake to call this oxid of iron ; as it is a mixture of oxid of iron and carbonate of iron.

Prop. 3. *Pure red oxid of iron may be obtained by driving out, with caloric, the reduced acid from a salt of iron.*

Illustration. Put some copperas, sulphate of iron, into an unglazed crucible, and heat it moderately until it becomes a dry white mass. Then put it into a crucible which will bear a high heat, and raise the heat until it becomes very red. Though copperas consists of the protoxid of iron and sulphuric acid, we obtain the peroxid. For a part of the sulphuric acid is decomposed, and thereby furnishes an other proportion of oxygen to the iron.

Application. Here the iron is left in the state of a peroxid, after the sulphuric acid is driven off in the state of gas. Sulphuric acid was at first obtained by heating copperas in earthen retorts, and bringing over most of the acid. Copperas being called green vitriol, this acid was called vitriolic acid ; and by some, the oil of vitriol, on account of its flowing like oil.

Prop. 4. *Sulphate of iron, (copperas,) is formed by the chemical combination of iron and sulphuric acid.*

Illustration. Put diluted sulphuric acid into a florence flask, consisting of about five times as much water as acid. Apply a very little heat, so

as rather to warm than heat the acid. Drop in iron filings until they will fall to the bottom quietly. Pour off the clear liquid into earthen plates. This is copperas in solution; and by a slow evaporation it may be crystallized.

Application. On this principle the copperas of commerce is manufactured; but the process is very different. Iron pyrites is moistened and exposed to the atmosphere a considerable time in a shallow vat or box. After it becomes covered with a crust it is dissolved in water, or leached, and evaporated. There is an extensive manufactory in Vermont; and a profitable one might be established on the east face of the Helderberg, 14 miles from Albany.

Prop. 5. *Iron will combine directly with sulphur by the agency of caloric, and form sulphuret of iron.*

Illustration. Perform this experiment as directed in preparing sulphuretted hydrogen gas. Or heat the end of a bar of iron almost to a white heat. Apply the hot end to a common roll of brimstone. The iron and sulphur will unite and form iron pyrites. A small roll of brimstone has been made to perforate a large bar of iron, when highly heated.

Application. Vast quantities of sulphuret of iron are found in the earth; but these substances seem to be more perfectly united than they can be by art. The native sulphuret is rarely used for composing sulphuretted hydrogen.

Sulphur and iron, when in combination, seem to be strongly predisposed to combine with oxygen. On this principle the oxygen is taken from an enclosed portion of atmospheric air, as direct-

ed under nitrogen. Lemery produced artificial volcanoes, by ramming with force into a large pot, a paste, made of 100 lb. of iron filings, intimately mixed with 100 lb. of pulverized sulphur, and just water enough to make a dense paste. This pot is then buried to a considerable depth in the earth, and between ten and twenty hours afterwards, it bursts out and burns with great force. I do not know that this experiment was ever repeated in America. It is said that no effect can be produced without a very large quantity of the mixture.

Though iron is mineralized with sulphur, oxygen and carbonic acid, it does not enter into many alloys. The principal alloy of iron known in the arts, is that of the sheet tin.

PRINCIPLE 2. MANGANESE.

Natural History and general Remarks.

Manganese is found in the state of a peroxid at various intervals along the west side of the Green Mountain range from Canada to the southwest corner of Massachusetts. It often accompanies the hematitic iron ore. It is generally found in the most recent primitive rocks, or in alluvial deposits consisting of these rocks, in a state of disintegration. In small quantities it is very extensively diffused in both continents; and is often found in quantities sufficient for working. No preparation is required; it is merely dug from the earth and sent to the bleachers. It is extremely difficult to reduce it to the pure metallic state.

Prop. 1. *The peroxid of manganese (usually called the black oxid) readily gives off its highest portion of oxygen on being subjected to the red heat of iron.*

Illustration. Produce oxygen from it as directed under oxygen.

Application. On this principle the manganese, as found in Trainer's mines at Bennington, Davy's mine near Whitehall, and other places, is very useful for converting muriatic acid into chlorine for making the bleaching liquor, as explained under chlorine.

Prop. 2. *The peroxid of manganese is reduced to the protoxid, and oxygen given off, by the application of an acid which combines with the protoxid only.*

Illustration. Pulverize some manganese very finely, and put it into a retort. Pour on it just enough strong sulphuric acid to moisten it, or to wet it moderately. Set the retort into the lead pot, and raise the heat, but not to a degree by any means sufficient to drive out the oxygen in the usual way, and oxygen gas will soon come over.

In this experiment the sulphuric acid, on being heated in contact with the manganese, combines with the protoxid, forming sulphate of manganese, and presses out the oxygen above that proportion.

Application. On this principle oxygen is furnished to the muriatic acid in the production of chlorine, as described under chlorine, at the instant of its disengagement from the soda of the table salt.

PRINCIPLE 3. TIN.

Natural History and general Remarks.

Tin has not yet been found on the continent of America, excepting a small quantity in Mexico.

The most extensive mine is that of Cornwall, in England. It is found in small quantities (always in granite or gneiss) in Spain, France, Ireland, Sweden, Bohemia, Saxony and the East Indies. It is mostly in the state of an oxid.

The tin foil is pretty pure, and the grain tin considerably so. What is called block tin was chiefly tin half a century ago. Now it is generally much alloyed with lead.

Tin alloyed with lead forms pewter. But it is most extensively used for covering the surface of thin sheets of iron, called sheet tin. When tin is thus applied in a pure state, it forms very useful ware. But the high price of tin encourages manufacturers to alloy the tin with lead and thus injure the ware.

Prop. 1. Tin is not oxidated at the common temperature.

Illustration. Wet a piece of tin foil and a case knife blade, and put them by, under the cistern or elsewhere, in a damp place. The next day show them to the class—the knife blade will be covered with rust, (or oxid of iron and carbonate of iron) but the surface of the tin will not be affected by oxygen.

Application. On account of this property of tin, iron plates are covered with tin, forming the tin-plate ware. Lightning rods are tipped with tin to prevent the points from rusting. Copper vessels are tinned inside for the same reason.

Prop. 2. Tin is oxidated, when heated so as to be brought to the state of fusion.

Illustration. Put some tin in an iron ladle, and heat it no higher than merely to melt it. The

surface will immediately absorb oxygen from the atmosphere sufficient to form the *protoxid of tin*, called the yellow oxid. This may be scraped off with an iron poker, when another similar pellicle will be formed ; and the succession may be continued until the whole mass is a yellow oxid.

If the protoxid of tin is put into a crucible, heated to redness, and continually stirred with an iron rod for some time, it will absorb another definite proportion of oxygen. It then becomes the *peroxid of tin*, called the white oxid, or putty of tin.

Application. The white oxid of tin is an excellent powder for sharpening edge tools, as knives, razors, &c. Also for polishing burnishers' glass lenses, &c. When this oxid is melted with glass it forms the white enamel used for clock and watch faces, &c.

Prop. 3. *Tin combines with mercury at the common temperature ; and at the time of its amalgamation with mercury will adhere to glass.*

Illustration. Put a drop of mercury into a wine glass, and drop into it small pieces of tin foil, which will become liquified and unite with the mercury. Continue these additions until the amalgam contains about half as much tin as mercury. Next spread a small piece of tin foil very evenly on the face of a smoothing iron or a piece of polished marble. Pour the amalgam upon it and rub it over the tin foil with the finger for about two minutes. Now press upon it a piece of dry clean glass. Press it down with such force as to press out all the uncombined mercury. Lay a weight upon the glass and leave it half an hour ; when

it may be taken up, and will be found to be a mirror.

Application. All looking glasses are made in this way. In the large way a marble slab is placed in an inclined position, so that the excess of mercury runs off and is saved for the next, &c.

Prop. 4. *Tin will form an imperfect alloy with iron.*

Illustration. Prepare a very thin slip of iron and scour it bright, dipping it several times, while scouring it, in very dilute sulphuric acid. Bend one end of it, so that it will fit the inside of the bottom of a crucible. Melt some tin in the crucible, and dip the bent end of the slip of iron into it. The tin will combine with the surface of the iron, and, if it is very thin, it will penetrate entirely through it.

Application. On this principle the sheet tin is manufactured. We may often find sheets of tin, which, on cutting them across, appear to be alloyed entirely through with the tin; and may be soldered after considerable is worn from the surface.

Prop. 5. *Tin will adhere to the surface of copper, if perfectly cleaned and heated.*

Illustration. Prepare a slip of copper by scraping it well with a knife and rubbing it over with sal ammoniac, (muriate of ammonia.) Now heat the copper over clean coals, which do not emit smoke; at the same time rubbing it over with rosin. While hot, and thus cleaned with the sal ammoniac and rosin, rub tin upon it in the solid state, which, being melted by the heat of the copper will adhere to it, giving it a silvery white surface.

Application. By a similar process copper kettles and other copper vessels are tinned inside. When the tin has worn off, any ingenious house-keeper might repair it in this way.

Prop. 6. *Tin dissolved in nitro-muriatic acid (aqua regia) forms the muriate of tin ; used for giving cochineal the scarlet colour.*

Illustration. Prepare the nitro-muriatic acid by mixing one part of muriatic acid with two of nitric acid, and put a very small quantity into a florence flask. Drop tin into it by small quantities, that it may not become too hot by the rapid union of the tin and acid. After the acid is saturated, dissolve some of it in water.

Application. Dissolve in water in a wine-glass a single cochineal insect of the shops, and drop in a little muriate of tin ; and it will become of a bright scarlet.

It may be made by dissolving the tin in strong muriatic acid, and then exposing it some time to the atmosphere. When muriatic acid is used, the tin takes the lowest portion of oxygen. It is then the *proto-muriate of tin*. When the nitro-muriatic acid is used, the tin takes the highest portion of oxygen. It is then the *per-muriate of tin*. But if the proto-muriate of tin is exposed to the atmospheric air, the tin takes another portion of oxygen, becoming the peroxid ; and the salt is of course the per-muriate of tin, which is used by dyers.

PRINCIPLE 4. ZINC.

Natural History and general Remarks.

Zinc is mostly found in the state of a sulphuret. It accompanies lead in most mines. It is found in

the Southampton lead mines in granite and gneiss. It is found in crystals of a waxy hue and almost transparent in the geodiferous lime rock (or swinestone) every where from Genesee river to 20 or 30 miles west of Niagara falls.

Alloyed with copper it forms brass. It has a strong attraction for oxygen—by the aid of sulphuric acid, it rapidly decomposes water. On account of its strong attraction for oxygen, it is used for the positive sides of the pairs of metallic plates in a galvanic battery.

Prop. 1. *Zinc forms a white oxid, very light and flocculent, on being melted and boiled in contact with atmospheric air.*

Illustration. Put into a crucible one ounce of zinc. Raise the heat so as to melt it, and then boil it a short time. Now raise the heat still higher and stir it with a rod. Flocculent flakes of the white oxid will begin to fly out of the crucible. Take the crucible out of the fire and hold it in fair view of the class, continually stirring it. The room will now be filled with the oxid, which is carried about by the air like fine down.

Application. This is the substance which was formerly called *white nothing*, (*nihil album*), *philosopher's wool* and *pompholix*. In medicine it was called flowers of zinc. When intended for medical use it is collected from the sides of the crucible, put into water, and stirred up awhile; then suffered to settle. Afterwards the water is poured off, and the oxid is dried and put up for use.

Fine filings of zinc may be oxidated and inflamed with explosion, by mixing it with oxymuriate of potash and striking the mixture with a hammer on an anvil.

Prop. 2. *Zinc combines with sulphuric acid and forms sulphate of zinc, called white vitriol.*

Illustration. Pour diluted sulphuric acid upon zinc, leaving the zinc in excess. After the action ceases, pour off the clear liquid, which is the white vitriol in solution. If this be evaporated slowly, crystals will be formed.

Application. By a similar process the white vitriol of the shops is manufactured.

The sulphuret of zinc, blende, is found in South-Hampton mines and other parts of New-England and the calamine is found in New-Jersey.

PRINCIPLE 5. CADMIUM.

Natural History and general Remarks.

Cadmium was lately discovered by Stromeger in carbonate of zinc. It has been found in silicious oxid of zinc in Derbyshire. Probably it may be found in the silicious oxid in Massachusetts. It resembles tin in not being oxidated at the common temperature, in being flexible and ductile. It is harder, however, and more tenacious. It is precipitated by zinc in a foliaceous form, like lead.

Should it ever be found in large quantities, it would be useful as a paint in the state of a sulphuret, of a lemon yellow colour.

SECTION 2. METALS WHICH ABSORB OXYGEN, BUT NOT WITH SUFFICIENT FORCE TO DECOMPOSE WATER; AND FROM WHICH OXYGEN CANNOT BE EXTRICATED BY HEAT ALONE.

(May become acids capable of combining with salifiable bases.)

General Remarks.

Five of the metals of this section may themselves become acids, and unite with other metals and with metalloids ; not as alloys, but as acids forming salts with them. The other seven cannot become acids. Copper is more useful in the arts, than all the other eleven metals of the section.

PRINCIPLE 6. ARSENIC.

Natural History and general Remarks.

Arseniate of cobalt is not uncommon in the hornblend rocks of this country. It is found in Hungary, &c. in the state of a red sulphuret, called *realgar* ; and in the state of a yellow sulphuret, called *orpiment*. Numerous combinations of this metal in the state of arsenious and arsenic acids, are given in the large works on chemistry. It is a deadly poison in the state of *arsenious acid*, which is the solid substance commonly called the white oxid of arsenic.

Prop. 1. *Arsenic may be united with sulphur, forming artificial orpiment.*

Illustration. Dissolve the arsenious acid in muriatic acid. Pour into this solution water well charged with sulphuretted hydrogen. A yellow precipitate of that variety of sulphuret of arsenic, called orpiment, falls down in a powder.

Application. Orpiment is used in the arts for an orange pigment. It is a beautiful mineral, either native or artificial.

Prop. 2. *Arsenious acid when thrown on ignited charcoal, gives off the scent of garlic.*

Illustration. Take burning coals upon a shovel, and sprinkle pulverized common arsenic of the shops upon it. White fumes will arise, which give the smell of garlic.

It is now well understood, that before the smell of garlic can be produced, the arsenious acid must be converted into metallic arsenic, and in a state of sublimation. Its projection on red hot charcoal will produce this effect, by its giving off its oxygen to the charcoal and becoming heated by it.

Application. As no metal gives a similar odour, this is a conclusive test, when we are sure that no animal or vegetable matter is present.

Prop. 3. *Arsenious acid may be detected by being reduced to the solid metallic state, or by tests in the liquid state.**

Illustration. 1. Mix arsenious acid, in the pulverized state, with three times its weight of black flux, and put the mixture into a glass tube closed at one end, (a long test glass is best) from three to six inches long, and the fourth of an inch in diameter. Apply the heat of spirit or of an Argand's lamp (hot coals will do) to the closed end. In a short time the metallic arsenic will appear in a brilliant form on the inner surface of the tube.

2. Dissolve arsenious acid in pure water by the application of a gentle heat. To the solution add sulphuretted hydrogen gas in solution, which has been made but a few minutes. An orange coloured precipitate will be produced.

* This proposition, together with its illustration and application, were obligingly furnished by Dr. T. Romeyn Beck, author of the work on Medical Jurisprudence. I take the liberty to add, that no physician, lawyer or judge, who has any respect for his own reputation, or for truth, ought to undertake any investigation, where human life or liberty is concerned, without studying that work.

3. To a similar solution of the arsenious acid, add a solution of carbonate of potash, to this mixture add a solution of sulphate of copper. A precipitate of a peculiar green will appear, called Scheele's green. [See Copper.]

4. In a similar solution of arsenious acid, bring two glass rods into contact, the one having been dipped in pure liquid ammonia and the other into a solution of nitrate of silver. A bright yellow precipitate will appear at the point of contact.

Application. These are the leading decisive tests of the presence of the deadly poison, called arsenic or ratsbane. It should be remarked, that great difficulties occur in the examination of it, when mixed with human fluids. This is generally the case in accusations of poisoning. The usual articles of food and drink often impair the correctness and vary the result of these tests. It must also be observed, that in some cases of real poisoning, none can be detected; owing probably, to its having been evacuated by vomiting.

No one ought ever to undertake the investigation of a case of supposed poisoning, who is not perfectly familiar with the ordinary effects of tests on arsenic—nor even then should he proceed to an examination without accompanying every step with a similar collateral experiment upon a specimen known to be arsenic.

PRINCIPLE 7. CHROME.

Natural History and general Remarks.

Chrome is found in the state of an acid, combined with iron, called chromate of iron. It is generally found in talcose rocks, or in granular

lime rocks, which contain serpentine. It is most abundant near Baltimore in Maryland; but is found in the granular lime rock at different intervals from near New-Haven in Connecticut to Canada.

When chromate of iron is pulverized and mixed with nitrate of potash, and heated to redness, a double decomposition takes place, and the chromate of potash is produced.

Chromate of potash is decomposed by metallic salts.

Illustration. Dissolve chromate of potash in pure water. Pour some of it in a solution of sugar of lead, and the beautiful yellow pigment, chromate of lead, will be precipitated. Pour it into nitrate of mercury, cinnabar red is produced. Into nitrate of silver, and carmine red is produced.

Application. The chromate of lead is now in general use as a yellow paint. An exceedingly small quantity of the chromate of lead mixed with white lead, gives the whole a beautiful yellow colour.

PRINCIPLE 8. MOLYBDENA.

Natural History and general Remarks.

Molybdena is found in the state of a sulphuret in rocks of granite and gneiss in numerous localities in the United States. It has the appearance of plumbago, but may be easily distinguished from that mineral with the blow-pipe. It gives off the smell of sulphur, and does not burn; whereas plumbago burns under a strong flame

from the blow-pipe, and does not give off the sulphurous smell. It is reduced to the metallic state with much difficulty. It is then soluble in no acid but nitric and nitro-muriatic. It is not used in the arts.

PRINCIPLE 9. TUNGSTEN.

Natural History and general Remarks.

It is found in rocks of granite and gneiss in Huntington in Connecticut, in the state of an oxid. Also in Sweden and other places. It is scarcely soluble in nitric acid, and not at all in any other acid. It is scarcely fusible in very high heat. It is capable of uniting with most other metals in the state of an acid. It is not used in the arts.

PRINCIPLE 10. COLUMBIUM.

Natural History and general Remarks.

Columbium has been found in the state of an oxid in Sweden and in America. Berzelius has lately discovered it in the granite of Haddam in Connecticut, which was sent to him by Mr. Pierce. The small black or very dark brown specks, which we have considered as a very singular kind of shorl, he has analyzed and found it to be the ore of Columbium. Though it may be alloyed with iron and tungsten, it has not hitherto been dissolved in any acid. It is not used in the arts.

(Not capable of becoming acids.)

PRINCIPLE 11. COPPER.

Natural History and general Remarks.

Copper is found native in many places. It is

also pretty common in the state of a sulphuret and a carbonate. It is chiefly manufactured from the copper pyrites, found in primitive rocks. But it is found in all the geological classes of rocks. Copper alloyed with from 12 to 18 per cent of zinc forms *brass*. When the proportion of copper is larger it forms *pinchbeck*. Six parts of copper, two of tin, and one of arsenic, form *speculum metal*. Three parts of copper with one of tin, form *bell metal*; and for little shrill sleigh-bells, &c. a little zinc is added. Copper and tin form *bronze* also, consisting of ten parts of copper to one of tin. It is much used in the arts.

Prop. 1. *Copper long exposed to moisture in a damp place, becomes a green carbonate at the surface.*

Illustration. Scrape off the green crust from a piece of copper and pour muriatic acid upon it, and it will effervesce, by the escape of carbonic acid. Pure copper will not effervesce, which may be shown also.

Application. All copper and brass utensils should be defended from moisture by tinning or by careful cleaning; for the carbonate of copper is very injurious if taken into the stomach.

Prop. 2. *Copper combines with sulphuric acid and forms sulphate of copper, called blue vitriol or Roman vitriol.*

Illustration. Boil copper filings in sulphuric acid, and the salt will be formed in the liquid state. This may be evaporated in the usual way.

Application. On this principle the blue vitriol of the shops is made; but not by a similar operation. The native sulphuret is heated and expos-

ed to air and moisture, and thereby the peroxid is obtained. Then the salt is readily formed by pouring sulphuric acid upon it.

Prop. 3. *Vinegar will both oxidate copper and form with it the salt called verdigris, (or acetate of copper.)*

Illustration. Cover a gallipot of warm vinegar with a polished piece of sheet copper. After some time it will be covered with a thin crust of verdigris. It is best for standing several hours, after cooling.

Application. Upon this principle, though with very different apparatus, the verdigris of the shops is made.

Prop. 4. *Copper has a strong affinity for ammonia, with which it will combine when in the state of salts or otherwise, and form various coloured compounds.*

Illustration. Rub together in a mortar about equal bulks of sulphate of copper and carbonate of ammonia. A purple compound will be formed.

Application. This is the ammoniuret of copper used in medicine.

Prop. 5. *Copper combines with arsenious acid and forms Scheele's green.*

Illustration. This may be effected by a double decomposition. Form arseniate of potash by dissolving pearlash in water and heating it, then by dropping in any quantity of common arsenic.—Dissolve sulphate of copper in hot water also. Let this preparation be made before lecture hour. At the time of lecture, pour the solution of sulphate of copper into the arseniate of potash. Arseniate of copper and sulphate of potash will be

formed. The arseniate of copper will precipitate, and the sulphate of potash, with the excess of pearlash or of arsenious acid, if any, will remain in the liquid state. Pour off the liquid, and wash the precipitate several times. This will be the true Scheele's green.

Application. So much reliance is placed on this process as a test for arsenic, that every student in chemistry ought to be well acquainted with this colour. See article Arsenic.

PRINCIPLE 12. ANTIMONY.

Natural History and general Remarks.

Antimony sold at the shops is in the state of a sulphuret generally. It exhibits a crystalline form; being mostly in needle form crystals. It has been found in very small quantities in different parts of the United States. In Europe it is found mostly in primitive rocks. It unites with three or four proportions of oxygen, according to Ure; the peroxid being the crocus of antimony of the shops.

When taken into the stomach in almost any form it causes vomiting. It does not contract so much on cooling as most other metals; it is therefore useful in the manufacture of printers' types.

Prop. 1. *Sulphuret of antimony will decompose water and form sulphuretted hydrogen gas.*

Illustration. Pulverize the common sulphuret of antimony, and put it into a retort. Pour in water and dilute muriatic acid, apply heat and collect the gas, as directed under sulphuretted hydrogen gas.

Application. When we wish for a test in haste, it is often a convenience to apply the sulphuret of antimony, without the trouble of preparing the sulphuret of iron.

Prop. 2. *Sulphuret of antimony may be reduced to the state of the peroxid of antimony by heating with saltpetre and sulphuric acid.*

Illustration. Pulverize very finely sulphuret of antimony and saltpetre. After pulverizing, mix the two powders very intimately in the proportion of one of antimony to five or six of the salt. Throw the mixture all at once, into a crucible previously heated to whiteness. Deflagration will immediately take place, during which oxygen will be given off by the saltpetre to the sulphur and convert chief of it into sulphurous acid ; and to the antimony, and convert most of it into an oxid. Now take off the crucible, let it cool, select all the orange yellow part of its contents and reject the rest. This is what is called in medicine *crocus of antimony*, or sometimes the metallic antimony. Though it is not entirely separated from the sulphur, it is sufficiently pure for common purposes.

Now mix this *crocus of antimony* with about twice its weight of sulphuric acid in a gallipot or tea-cup. After mixing and remaining a little while, put it into a clean iron ladle, and boil it down to a perfectly dry mass, frequently stirring it with an iron rod. This dry powder, when well washed, is nearly pure peroxid of antimony.

Application. When antimony is brought to the state of an oxid, it is in a convenient state for applying to various uses. It may easily be prepared for alloying with lead for the manufacture of printing types, &c.

Prop. 3. *Oxid of antimony will combine with tartaric acid, and form the tartrate of antimony, called tartar-emetic.*

***Illustration.** Dissolve some supertartrate of potash (to be described under vegetable acids) in water, and put into it an equal weight of dry oxid of antimony. Pour this mixture into a clean iron ladle, and boil it about fifteen minutes. Let it stand about a minute to settle any impurities, and then pour the liquid into any clean vessel to set by to crystallize. Or it may be cleaner to strain it through paper. After it cools and stands awhile crystals of tartrate of antimony will be formed. The supernatant liquid may be poured off and evaporated a little, and set away to crystallize again. These crystals may be washed and put up for use.

Application. This is the important medicine so long in use, under the name, tartar-emetic. It is rendered more pleasant, by dissolving the crystals in boiling water, equal to about fifty times their weight. Then adding about a third more good wine than to equal the quantity of boiling water. This is called tartarized wine.

PRINCIPLE 13. BISMUTH.

Natural History and general Remarks.

Bismuth is found in a pure metallic state in Huntington, Connecticut. A pretty large specimen was found among the pebbles in a stream of water near Lake George. It is found in mines of gold, with copper, &c. but is not very abundant.

Prop. 1. *Bismuth combines with nitric acid,*

and forms nitrate of bismuth; the most delicate sympathetic ink.

Illustration. Whittle off a little bismuth into a wine-glass. Drop in a little common nitric acid diluted with half as much water. Violent action will commence; when it ceases the nitrate will be found in the liquid state.

Dip a clean pen into it and write as with ink. Hold the paper near a fire, but not so near as to heat it, the letters will become invisible. Having shewn the paper to the class without any visible letters, now dip it into water, or hold it in steam over boiling water, and on taking it out the letters will become visible and appear as if written with pale ink.

Application. If a letter be written on ordinary subjects with ink, sentiments of a more delicate nature, expressive of sympathies which it is desirable to conceal from prying post-office clerks, &c. may be expressed in this liquid between the ink lines. The confidential correspondent has only to dip the letter in water before he may catch the fugitive sigh and feast his fervid imagination on the half-told assurances. But the writing will soon disappear, and leave not a vestige to prove a forgotten promise.

Prop. 2. *Water precipitates oxid of bismuth from liquid nitrate of bismuth.**

Illustration. Pour into the liquid nitrate of bismuth, prepared as in the last experiment, eight or ten times its bulk of water, and the white oxid will be precipitated in a fine powder.

Application. This white oxid, after being washed and dried, is put up for medical use. It is

* This experiment with antimony will give the same result.

said to be an excellent tonic. It forms the basis of the most delicate face paints, or pigments for other uses. But it is so readily tarnished by sulphuretted hydrogen, that a painted face, where it has been applied, will become tawny at the approach of a small quantity of that gas. Consequently those who wear painted faces have two good reasons for retreating from the attack of nauseous scents.

Remark. The other five metals belonging to this division of the second section, need not be introduced for experiments in the course proposed. Instructors who think proper to experiment upon them, are referred to larger works.

PRINCIPLE 14. COBALT.

Natural History and general Remarks.

Cobalt is found combined with arsenic and with sulphur in hornblende rock, and in the same rock passing into gneiss, from Vermont to Long Island sound, passing down on the east side of Connecticut river to near Haddam in Connecticut, and then crossing to the west side. Though this range is very extensive, it has never been found in it in sufficient quantities for working.

It is sold in the shops in the state of an imperfect oxid, called zaffre. The pure metal is reddish grey.

Prop. 1. *The zaffre gives to glass or to an alkali a violet blue colour.*

Illustration. Mix finely pulverized flint and borax and put in a small quantity of zaffre. Melt this mixture with pretty strong heat in a crucible ;

and a small blue glass will be produced. Or put a little zaffre in borax alone, or in pearlash, and melt the mixture.

Application. The smalt sold in the shops in powder, is merely pulverized glass prepared as above.

Prop. 2. *A blue or green sympathetic ink is made with zaffre and muriatic acid.*

Illustration. Drop a tea-spoon of zaffre into the third of a wine-glass of nitro-muriatic acid. After standing a while, write on paper. The writing will be invisible cold, but on heating the paper the writing will be blue unless there is a little iron in the zaffre, which will give it a green hue. If a little common salt in solution had been added, the writing would disappear on removing from the fire.

Application. This has no farther application, than as it illustrates the colouring properties of the oxids of metals.

PRINCIPLE 15. TITANIUM.

Natural History and general Remarks.

Titanium is always found in the state of an oxid in primitive rocks, particularly with tremolite in granular limestone. It was considered as a subspecies of shorl until within twenty or twenty-five years. It is always brownish red, very difficult to reduce, and its properties little known. Excellent crystals are found between Greenfield, Massachusetts, and the Green Mountain range. Several localities have been discovered in that district.

PRINCIPLE 16. TELLURIUM.

Natural History and general Remarks.

Tellurium is found in Huntington in Connecticut, associated with tungsten, bismuth and silver. It is always more or less alloyed with other metals. It is chiefly found in Transylvania.

It resembles antimony considerably. It burns with a bluish flame before the blow-pipe, giving the odour of horse radish. Not used in the arts.

PRINCIPLE 17. CERIUM.

Natural History and general Remarks.

Cerium is found in Sweden in the state of an oxid. The protoxid is white, the peroxid is red. It has scarcely ever been reduced to the metallic state. The peroxid is generally combined with silex. It is not used in the arts; and scarcely known in the laboratory or the cabinet.

PRINCIPLE 18. URANIUM.

Natural History and general Remarks.

Uranium is found in the state of a black oxid and of a green oxid. It is found in small masses in veins of ores in primitive rocks in Maryland and in some parts of Europe. The green oxid is a beautiful mineral; but it is extremely difficult to reduce either of the oxids to the metallic state. It is not used in the arts.

SECTION 3. METALS WHICH DO NOT RECEIVE OXYGEN, EXCEPTING FROM STRONG ACIDS.

PRINCIPLE 19. GOLD.

Natural History and general Remarks.

Gold is never found mineralized, but almost al-

ways in the state of an alloy with silver or with some other metal. It is found in most countries in the sands of rivers; but when found in place it is generally contained in primitive rocks. It has lately been found in considerable quantities in North Carolina; a particular description of that locality has been communicated to Silliman's Journal by Professor Olmsted. Gold cannot be tarnished by oxidation on exposure to water or the atmosphere.

Prop. 1. *Gold may be dissolved by nitro-muriatic and by oxy-muriatic acids, and by no other acid.*

Illustration. Put a little muriatic acid into a wine-glass, and twice as much nitric acid in another wine-glass. Drop into each a small piece of gold leaf, and neither of the pieces will be dissolved. Now pour the contents of one glass into the other, and both pieces of gold will be immediately dissolved.

Application. This mixture is the *aqua regia* of old authors. The new compound formed is muriate of gold; but it seems that gold requires the joint action of the two acids, the nitric acid affording oxygen for oxidating the gold, and then the muriatic acid unites with it.

Prop. 2. *Iron, silver and copper may be covered with a thin coat of gold, which is called gilding.*

*Illustration. Pour into a saturated solution of muriate of gold (that is, where there is no excess of acid) about twice as much sulphuric ether. Now brush upon a clean polished surface of iron or steel some of this liquid. The ether will soon

evaporate and leave the gold covering the surface.

To gild silver or copper, heat gold and mercury together in a crucible, one part of gold to about eight of mercury, until they are completely alloyed; then throw the hot alloy into cold water. Having wet the silver or copper with diluted nitric acid, brush on the alloy with a fine brush (a wire brush is best) as uniformly as possible. Then drive off the mercury with heat, placing the gilded metal over hot coals. Afterwards the surface must be polished with a burnisher. The only objection made to this method by artists is, that it is very difficult to lay on the alloy evenly. But old artists learn to brush over the bare spots while it is heating, being careful to avoid inhaling the mercurial fumes.

Application: This method of gilding iron is undoubtedly very perfect; but it is desirable that some better method for gilding the other metals should be devised. Most substances to be gilded may be conveniently covered with gold leaf. Gold is so very ductile, that the leaves are made very thin. It is said that about a pound of gold may be hammered out between beater's skins so very thin, as to furnish enough to gild a wire of sufficient length to surround the earth.

Prop. 7. *Adulterations of gold coin may be detected, without an analysis, by taking the specific gravity.*

Illustration. Take the specific gravity of a piece of gold coin, according to the directions given in the introduction. If its specific gravity is 17.157, it is lawful coin.

Application. There is no metal so heavy as gold, excepting platina. And such is the value of platina, that there is no danger of its being alloyed with that metal. Standard gold coin is an alloy of one of copper to eleven of gold, in order to make the coin harder, that it may wear the better. The specific gravity of perfectly pure gold is 19.3. Copper, silver, and most other metals, which are alloyed with gold, may be easily separated from gold by nitric acid. For if the alloy be in fine filings, the nitric acid will dissolve the other metals, and leave the gold in a black powder. This powder may be separated and melted down into a pure mass. But the most common method adopted by artists is, to melt the alloy with sulphuret of antimony. The other metals become sulphurets, and the gold will unite with the antimony and fall to the bottom of the crucible. After cooling it may be separated. Now melt the alloy of gold and antimony, boil it at a white heat, and the antimony will become volatilized and fly off.

PRINCIPLE 20. SILVER.

Natural History and general Remarks.

Silver is found alloyed and mineralized with numerous substances. Sulphur, alumine, antimony, lead, arsenic, silver, copper, mercury, carbonic acid, muriatic acid, &c. have been found combined with silver. A little silver appears in most lead mines; with this exception silver is a rare ore in North America. It is very abundant in South America, where it is found in the metaliferous limestone.

Silver cannot be tarnished with oxygen by any

exposure at the common temperature. It is very malleable and ductile, but not so ductile as gold.

Prop. 1. *Silver coin is alloyed with copper, as $12\frac{1}{2}$ to 1 ; from which alloy silver may be obtained pure, by forming a nitrate of it, and then precipitating it by solid metallic copper.*

Illustration. Put some nitric acid into a wine-glass diluted with an equal bulk of water. Drop into it a six cent piece, and let it remain until action ceases. Now take out the undissolved silver, and put in a plate, or a cent, of perfectly clean bright copper. The silver will be precipitated after a short time. Wash the powder several times ; and put a little liquid ammonia into the water for the first washings. Now melt down the powder into a solid mass, which will be pure silver.

Application. It is very convenient to have a ready method for obtaining pure silver from coin when it is wanted for a particular purpose. But silver is harder and will wear longer if it contains a little copper. Ever so small a quantity of copper, however, in a finger ring or in any jewelry, which comes in contact with the skin, will tarnish.

Prop. 2. *Silver will combine with nitric acid and form the nitrate of silver, called lunar caustic, or lapis infernalis.*

Illustration. Put nitric acid into a wine-glass diluted as before. Drop in a piece of pure silver, and let it remain till action ceases. Take out the remainder of the silver. Evaporate the solution to a solid salt.

Application. This salt is used in medicine, and for a test of the presence of muriatic acid in min-

eral waters, &c. An *indelible ink* is also made, by dissolving it in pure water and then adding a little vinegar, also adding a little gum-arabic to give it consistency. If a piece of cotton or linen be dipped into a weak solution of pearlash, and then dried under a moderately heated smoothing iron, it may be written on with a clean pen dipped in this solution, and the writing will never wash out. Those who do not wish to take the trouble to make the lunar caustic, may always find it at every druggist's shop.

Prop. 3. *Copper may be coated with silver, if rubbed with it when in the state of a powder combined with some of the salts.*

*Illustration. Make a powder as follows : take a few grains of silver in powder, as precipitated by copper in the first experiment, after it is washed and before melting—about an equal weight of alum or a little more—six times as much table salt—also six times as much tartrate of potash. Pulverize all these articles and rub them well together. Rub the clean bright surface of a piece of copper with this powder and it will be silvered.

Application. Though this silvering is not very durable, it will defend the surface of copper from tarnishing while it lasts ; and it may be easily renewed. Plating copper is much preferable. This is done by brazing on a thin bar of silver upon a thick bar of copper. Then both are rolled out into the proper thickness for use.

Prop. 4. *Horn-silver of the shops is formed by an oxid of silver and muriatic acid.*

Illustration. Pour muriatic acid into a solution of nitrate of silver.

Application. If this salt is well prepared, so as to be almost a pearl white, it will become violet and then black, if exposed to the sun's rays in a thin test-glass—a good illustration of the decomposing power of light.

Prop. 5. *Nitrate of silver heated with alcohol and an additional portion of nitric acid, may be formed into an explosive or fulminating powder.*

***Illustration.** Pulverize a very few grains of lunar caustic of the shops. Put it into a florence flask, and add about five times as much alcohol and about five times as much strong nitric acid. If a pretty violent effervescence does not commence soon, apply the heat of a candle. As soon as it does commence, remove the candle. As soon as a thick white precipitate commences, the effervescence may be regulated by occasionally pouring in a little pure water. After the action has ceased let it stand and settle a short time; then pour off the supernatant liquid and wash the powder several times in pure water. Spread it on paper and let it dry and drain awhile. Now put a grain of it on the blade of a case knife and hold it over a candle. As soon as the knife is a little heated it will explode. It will also explode violently by compression or friction.

Application. This is an interesting illustration of the wonderful force exerted when solids are suddenly converted into gases. But this preparation ought not to be made before a class; neither ought it to be exhibited in the course proposed here. I give the description of Mr. Silliman's method, for the amusement of those who have leisure to attend to it in a private office. It is the most powerful

and the most dangerous of all known fulminating substances.

PRINCIPLE 21. PLATINA.

Natural History and general Remarks.

Platina has always been found in small grains in alluvial formations; but from the character of the sands in which it is found, it is probable that its original associations are in primitive rocks. It is mostly found in South America. It is never found pure, but is alloyed with iron, copper, lead, osmium, rhodium, iridium and palladium; though these alloys constitute but a small part of the mass of the ore.

Platina is the heaviest of all metals, least expansible by heat, most difficult to melt or to unite to oxygen. It is therefore preferable to all metals for pendulum rods, for inch measures, for crucibles, for reflecting telescopes, and conductors for the galvanic battery.

It will be very difficult to experiment much upon platina in the proposed course. It being the most fixed and infusible of all metals, it is polished and used as a concave reflector in the most powerful telescopes, where glass would melt or break. For crucibles and other uses it is employed in the laboratory. It has not been much used in the arts, on account of its scarcity.

Platina may be dissolved in nitro-muriatic acid, and will then form muriate of platina, which is a test for potash.

*Illustration. Put a grain or two of platina into a florence flask, and pour in a small quantity of nitro-muriatic acid and apply a little heat. It

will dissolve very slowly ; but in a few days muriate of platina will be formed. Dissolve a little muriate of soda (common salt) in a wine-glass, and a little saltpetre in another. Put a few drops of the muriate of platina into each ; and it will produce no effect on the solution of muriate of soda, but will give a yellow precipitate from the solution of saltpetre.

Application. It is often a convenience to be able to distinguish potash from soda, without going the round of evaporation to dryness, and then waiting to see whether it will deliquesce or effloresce.

PRINCIPLE 22. OSMIUM.

Natural History and general Remarks.

Osmium is found in small quantities alloyed with platina. A black powder remains after dissolving the grains of platina in nitro-muriatic acid. If this powder be heated with saltpetre, the oxid of osmium is sublimed ; which gives a very pungent odour. It is very soluble in water, and becomes purple with an infusion of galls. It gives up its oxygen to all the metals but gold and platina.

PRINCIPLE 23. IRIDIUM.

Natural History and general Remarks.

Iridium is always alloyed with osmium and associated with native platina of South America. It is scarcely acted upon, or not at all, by nitro-muriatic acid. By fusion with potash it becomes oxidated ; and then it is soluble in the three strong acids. Not used in the arts.

PRINCIPLE 24. PALLADIUM.

Natural History and general Remarks.

Palladium is found in grains of platina and gold in Brazil. It resembles platina more nearly than any other metal. But its specific gravity is but about half that of platina. With nitro-muriatic acid it forms a deep red solution. Not used in the arts.

PRINCIPLE 25. RHODIUM.

Natural History and general Remarks.

Rhodium is a doubtful metal ; though Wallaston and Descatils suppose they find it sufficiently characterized. Its specific gravity is about half that of platina. It is not malleable, is infusible and insoluble in acids ; but it is soluble in nitro-muriatic acid when alloyed with copper, lead or platina. Not used in the arts.

SECTION 4. METALS WHICH ABSORB OXYGEN, AT LIMITED TEMPERATURES, AND GIVE IT WHOLLY OFF AT HIGHER TEMPERATURES.

Remark. The character of this section will be shown by heating red lead.

PRINCIPLE 26. MERCURY.

Natural History and general Remarks.

This is the quicksilver or *argentum vivum* of old authors. It is generally found in secondary rocks, in the state of a sulphuret, called cinnibar. It is in the solid state at about 40 degrees below

zero, that is, about 72 below freezing—it is in the liquid state to about 600 above freezing, when it is evaporated. It is much used in medicine and in the arts. Though its most general effect upon the human system, when used as a medicine, is to correct the morbid, and restore the healthy, secretions ; yet some of its operations have not hitherto been explained.

Prop. 1. *The black oxid or protoxid of mercury is produced by agitating mercury in contact with atmospheric air, or by precipitating it from calomel with potash.*

Illustration. The easiest method of producing the black oxid is, to put about a gill by measure of mercury in a strong quart stone jug, and let some person take it into a carriage, who is about to travel forty or fifty miles over a rough road. A considerable quantity of the black oxid will be formed in the jug. But the mercury of the shops is often alloyed with lead, which will produce a black powder in abundance, resembling protoxid of mercury. The most perfect protoxid of mercury is obtained by dropping calomel into a solution of potash.

Application. The black oxid formed in this way illustrates the principle of oxidation very satisfactorily. This is the *Ethiops per se* of old authors.

Prop. 2. *The red oxid or per-oxid of mercury is produced, by heating mercury in contact with atmospheric air, or by precipitating it from corrosive sublimate.*

Illustration. Put a little mercury in a florence flask and keep it at a heat a little below boiling or subliming in a sand bath, for several hours. If

the temperature is managed cautiously it will become a red oxid in the form of scales at first ; but if the heat is carried a very few degrees too high, it will sublime in the pure metallic state, according to the character of this section. The per-oxid of mercury is best obtained by precipitating it from a solution of corrosive sublimate by lime water.

Application. This was formerly called *precipitate per se*, as distinguished from the red precipitate. It is now called *hydrargyri oxydum rubrum* in the pharmacopœias.

Prop. 3. *Mercury combines with nitric acid and forms nitrate of mercury.*

Illustration. Put some mercury into a wine-glass and pour in nitric acid diluted with about one fourth its measure of water. Let the mercury be in excess and nitrate of mercury will form and crystallize, without any evaporation.

Application. This salt is used in medicine by some physicians. It is also used as a test, and in several chemical experiments.

Prop. 4. *If a solution of nitrate of mercury be poured into a solution of phosphate of soda, a precipitate of phosphate of mercury will be formed.*

Illustration. Dissolve the common phosphate of soda of the shops in water. Pour into it a solution of nitrate of mercury, which will instantly produce an almost solid precipitate of phosphate of mercury. For the phosphoric acid has a stronger affinity for mercury than nitric acid, and nitric acid has a stronger affinity for soda than phosphoric acid ; consequently the double decomposition is very rapid.

Application. The phosphate of mercury is used in medicine.

Prop. 5. *The nitrate of mercury may be reduced by heat to the nitric oxid of mercury, called red precipitate.*

Illustration. Put the salt into a gallipot and apply a moderate heat, until it is reduced to a dry white or yellowish mass. Then pulverize it very finely in Wedgewood's mortar, and put it into a ladle. Raise the heat moderately, until the powder becomes bright red; it will then assume the appearance of scales. It may be heated to a degree at which it will be red, then yellow on cooling, then red again, &c.

Application. This is the red precipitate used in medicine. This is the substance which is boiled with prussian blue to obtain the prussiate of mercury, from which the prussic acid is disengaged.

Prop. 6. *Sulphur and mercury will unite without heat by being rubbed together, and form the black sulphuret, called Aethiops mineral.*

Illustration. Put equal quantities by weight of mercury and pulverized sulphur in Wedgewood's mortar, and rub them with the pestle until there is no appearance of liquid mercury.

Application. This sulphuret is used in medicine.

Prop. 7. *Mercury will combine with sulphuric acid by heat, and form the per-sulphate of mercury.*

***Illustration.** Put some mercury into a Florence flask and pour in about as much strong sulphuric acid; it is better to put in about one eighth more of the acid by weight. Set the flask into the lead pot or over coals and boil the contents mo-

derately, until it becomes a dry white mass. Now take the flask from the fire and cork it up tight, or it will absorb water very soon from the atmosphere and become liquid.

Application. This caustic salt is not much used in this state; but it is used for making corrosive sublimate and calomel. An article in the materia medica called *turpeth mineral* is made by merely throwing this salt into boiling water, after it is finely powdered. It immediately becomes a yellow powder, and must be washed several times in warm water before it is put up for use.

Prop. 8. *If per-sulphate of mercury and muriate of soda be rubbed together, a double decomposition will take place, and per-muriate of mercury, called corrosive sublimate, will be produced.*

***Illustration.** Put dry per-sulphate of mercury into Wedgewood's mortar and about a third more by weight of common table salt. Rub them well together, and put the mixed powder into a florence flask, stopping it loosely with a glass stopper. Set the flask into the lead pot and apply heat. A decomposition will take place, and the corrosive sublimate will be sublimed: That is, by raising the heat gradually it will shoot up in crystals along the sides and into the neck of the flask. After the crystals stop shooting up, take out the flask and break a hole through the bottom carefully, still keeping it in an upright position. The hole must be about as large as the whole bottom of the flask, through which all the black residue must be discharged. Now scrape out the crystals, and put them up for use.

Corrosive sublimate may be produced by making nitrate of mercury with heat, (that is, by drop-

ping very small globules of mercury at a time into boiling nitric acid) and then pouring into a solution of it, a solution of common salt.

Application. The first method exhibits the principle in a cheap way. But a very different apparatus is adopted, for manufacturing corrosive sublimate in a large way. It is called oxymuriate of mercury; but as it consists of muriatic acid combined with the peroxid of mercury, without any oxymuriatic acid, it is properly the per-muriate of mercury. It is a deadly poison.

Prop. 9. *Per-muriate of mercury may be reduced to the proto-muriate, (called calomel) by being rubbed with an additional portion of mercury, and the mixture heated to the state of sublimation.*

***Illustration.** Put corrosive sublimate into Wedgewood's mortar, and add about half as much by weight of mercury. (It is rather more safe to add about an eighth more mercury.) Rub them well together, until there is no appearance of mercury; it having all become a powder. Now put it into a florence flask and sublime it, as when making the corrosive sublimate. After subliming once, it ought to be scraped out, powdered in the mortar and sublimed again, in order to be pure and fit for use.

Calomel may be made by pouring a solution of common salt into a solution of nitrate of mercury made cold. It is best to add a little muriatic acid to the solution of common salt.

Application. This is the calomel used in medicine. It is called sub-muriate of mercury. But as it consists of muriatic acid combined with the protoxid of mercury, its true name, according to

correct nomenclature, is proto-muriate of mercury. But if we adopt the chlorine doctrine, the sublimate of mercury is *perchloride* of mercury, and the calomel is *proto-chloride* of mercury.

This method of preparing those salts appears wasteful; but the florence flasks can be had for half a dollar per dozen, and there is no other method within my knowledge of experimenting so cheaply.

Prop. 10. *Nitrate of mercury, heated with alcohol, may be formed into an explosive, or fulminating powder.*

*Illustration. Make the nitrate of mercury by heating the mercury with about ten times as much nitric acid, by weight; which will be in a liquid state. After it is cool, pour it into a florence flask with about one fourth more alcohol. Apply a moderate heat until effervescence commences, and no longer. After effervescing awhile, and producing fumes on the surface, a powder will begin to be precipitated. When the process ceases, pour off the liquid, wash the powder several times immediately in pure water, and then dry it on paper. It must be dried without exposing to much heat, or it will explode while drying.

Application. By striking a small quantity of this powder with a hammer on an anvil, it will explode violently. It will explode by compression under the feet on a pavement, if well dried. It is used in various mixtures for small fire-works, &c. Though it is not so dangerous an article as fulminating silver, it ought to be made in very small quantities only, and very little exploded at once. As it explains no principle, which cannot as well be explained by experiments of less danger, it

will generally be most advisable to omit it in the course here proposed.

Prop. 11. *Corrosive sublimate may be reduced to imperfect calomel by animal albumen.*

Illustration. Beat the white of an egg in water until it is well mixed with it. Then pour it into a solution of corrosive sublimate ; and a precipitate of calomel will soon appear.

Application. When a person takes corrosive sublimate into the stomach by accident, if it is immediately discovered, and the white of several eggs is swallowed, the poisonous effect will probably be checked. Milk or blood, if taken in the stomach freely, may check its operation.

Prop. 12. *Corrosive sublimate, the per-muriate of mercury, may be detected by an orange-yellow precipitate, made with lime-water.*

Illustration. Dissolve some of this corrosive salt in water, and then pour into it some lime water ; immediately an orange-yellow precipitate will appear.

Application. Although this is a good test, there is so much difficulty in obtaining the salt from the stomach of a dead body, that circumstantial evidence ought rather to be relied on, than the opinions of physicians founded on such an examination. It is more soluble than arsenic ; consequently more difficult to obtain from among the liquid contents of the stomach.

PRINCIPLE 27. LEAD.

Natural History and general Remarks.

Lead is generally found mineralized with sul-

phur, in an oar called galena. It is much used in the arts in the metallic state. It is alloyed with tin, forming pewter. Good pewter consists of one part lead to four of tin ; but most of the pewter of the present day is chiefly lead. Solder, called plumber's solder, consists of equal parts of lead and tin melted together.

Prop. 1. *Lead receives its lowest proportion of oxygen at a low red heat, while exposed to atmospheric air ; also from the decomposition of an acid, with which it is combined as the base of a salt.*

*Illustration. Melt some lead in a ladle, and scrape off the pellicle which forms on its surface several times, or until a sufficient quantity is obtained. Part of this is oxidated, and part is not. Now put this into the ladle by itself and expose it to a low red heat, continually stirring it with a rod until it becomes of a yellow colour. This is the protoxid, yellow oxid, or *massicot*.

Or it may be obtained by forming the nitrate of lead in the same manner as directed for forming the nitrate of mercury, and then by heating the salt to redness in a ladle, covered over pretty closely ; the acid is driven out, leaving the protoxid of lead.

Application. This is the *massicot* used in the arts. It is also an useful powder for setting a fine edge to razors, for polishing burnishers, &c.

Prop. 2. *The protoxid of lead will become the deutoxid, by exposing it to atmospheric air in a strong heat, not quite bringing the powder to a state of fusion.*

*Illustration. Put some *massicot* into a ladle, and cover it over loosely with an earthen or iron

plate, and raise the heat. Raise up one end of the plate and stir it often, until it becomes of a bright red. Care must be taken not to raise the heat so high as to drive off the previously acquired oxygen, and thereby bring it again to the state of pure melted lead. It is, in fact, difficult to perform this operation with small quantities.

Application. This is *red lead* or *minium*, used by painters. On this principle, though with very different apparatus, red lead is manufactured for the shops. But the red lead of the shops is generally very impure. It often contains red ochre, silex, alumine, muriate of lead, sulphate of lead, &c.

Prop. 3. *Minium becomes litharge by heating a considerable time in as high a heat as it can bear, without parting with its oxygen.*

*Illustration. Put some red lead into a ladle, and heat it until it is partly melted, so that it begins to be agglutinated in a kind of scales.

Application. This is the semi-vitreous oxid of lead, usually called *litharge*. It is not so bright a red, but is a more durable colour.

Prop. 4. *By raising the heat very high, oxid of lead gives its oxygen wholly off, and becomes pure lead again.*

Illustration. Put some red lead into a crucible and raise the heat as high as the white heat of iron; and pure metallic lead will be found in the crucible.

Application. This last experiment is an illustration of the distinctive character of this section.

Prop. 5. *Red oxid of lead will decompose muriate of soda, with heat, and form the patent yellow.*

Illustration. Pulverize common table salt very finely and put it into Wedgewood's mortar. Put in with it twice as much finely pulverized red lead after it had been heated until it become yellowish, or the same quantity of litharge. Rub them well together first; then add water, a very little at a time, and continue rubbing until a paste is formed. Muriate of lead will now be formed, and the soda will be disengaged. Pour in a large quantity of water and wash it several times. The soda will wash out and leave a white mass. Dry this mass and then melt it in a crucible; and a beautiful substance will be formed, called *patent yellow*.

Application. The patent yellow is one of the most durable pigments, and may be made very good in this way.

Prop. 6. *Carbonate of lead, called white lead, is formed by double decomposition on mixing nitrate of lead and pearlash.*

Illustration. Make nitrate of lead as before directed, and dissolve it in water in a wine-glass. Pour into it a solution of pearlash, and a white insoluble precipitate will fall down. Let the liquid be poured off, and the powder washed several times.

Application. This is the *white lead* of painters in its purest state. It is generally made in the large way by applying the vapour of vinegar to sheet lead. It will of course contain some acetate of lead and other impurities.

Prop. 7. *White lead, carbonate of lead, dissolved in vinegar, forms sugar of lead.*

***Illustration.** Put some white lead into a Florence flask. Put in about ten times as much good sharp vinegar, (distilled vinegar is best.) Shake it up several times and let it stand until the vinegar tastes sweet. Add more vinegar and continue adding by littles, until it will remain sour. Evaporate and crystallize in the usual way.

Application. This is the acetate of lead, or sugar of lead, used in medicine. It is called sugar of lead on account of its sweet taste.

Prop. 8. *Lead is precipitated from the state of a salt in the metallic state by metallic zinc.*

Illustration. Dissolve sugar of lead in thirty or forty times its weight of water. Fill a decanter with this solution. Suspend a small clean bright piece of zinc in the liquid by a thread, which is held by being compressed by the side of the stopper. Set the decanter in a conspicuous place in the class-room where it may remain a day or two undisturbed. The acetate of lead will be decomposed. The lead will cover the zinc with leaves shooting out in a curious manner, while the sour taste of the vinegar is partly restored.

Application. Zinc having a stronger affinity for oxygen than lead, it takes so much from it, that it cannot hold the vinegar any longer in combination with it.

PRINCIPLE 28. NICKEL.

Natural History and general Remarks.

Nickel is generally obtained from the sulphuret. It is found alloyed with iron in meteoric stones. Its colour, when pure, is between those

of silver and tin ; but it generally exhibits a pale flesh coloured tinge. Ure says it is magnetic ; Accum is just as positive that it is not magnetic. Others differ in opinion on this subject. Accum, Chenevix and others say, it is the iron which is alloyed with the nickel, that attracts the magnet. It is a rare metal.

Nickel forms a salt with nitric acid, which may be made to exhibit several colours.

Illustration. Put an excess of nickel into a strong solution of nitric acid, and let it remain until the acid is saturated. The liquid will be the green nitrate of nickel in solution. Pour in liquid ammonia in excess and a blue precipitate is formed ; and this will become reddish purple in a few hours, which may be brought back to a green colour by an acid.

Application. Nickel is not much used, excepting as a subject of philosophic speculation in regard to its magnetism, its presence in all meteoric stones, and its varying hues as the basis of a salt.

ORGANIC SUBSTANCES.

General Remarks.

Under organic substances are included the subjects of the vegetable and animal kingdoms. The ultimate elements, constituting all vegetable and animal substances, have been described, and their chief properties illustrated by experiments, in the preceding part of this work. But when those simple substances are arranged according to the laws of organization, and endowed with the living principle, phenomena are induced which elude the researches of the chemist.

The constituents of vegetable and animal matter are properly divided into *proximate* and *ultimate elements*. The proximate elements are those compounds into which animal and vegetable matter may be resolved, and still retain properties most nearly resembling these organic substances, before they were subjected to the process of decomposition. Such as resin, starch, gum, glue, albumen, oil, &c. The ultimate elements are the simple substances into which they may be resolved, by a thorough analysis. Such as oxygen, carbon, &c.

Much progress has been made in this department of chemistry within a few years. But the complex nature of organic matter presents many difficulties, and the analyses are very slow and tedious. By following the directions given by such extensive and learned works as those of Thompson, Ure, M'Neven's Brand, Gorham, Silliman's Henry, &c. we may succeed in repeating the experiments, necessary for demonstrating the truth of those principles, adopted by the great philoso-

phers of the age. But such a course of experiments would require the labour of many months, or perhaps of years.

Having become practically acquainted with the most important properties of all the elementary constituents of animal and vegetable matter, we are now prepared to understand the descriptions given us by those, who have patiently and laboriously investigated them. We must therefore content ourselves with the history of their labours, and rely upon the truth of their experiments; as we do upon the astronomical calculations of Newton, Le Lande, Herschel and others.

While animals and vegetables are in the living state, that undescribed something, called the living principle, renders their operations intricate and complicated. Two active principles, the *living principle*, and the principle of *chemical affinity*, are perpetually at war with each other. The latter is disposed to derange the organic structure, and to form new chemical compounds. But the former is the more powerful, and resists the incessant attacks of the latter. Chemical affinity is exerting its energies every moment of our lives to convert our bodies into the most odious gases, and inorganic liquids and solids. But the living principle maintains its empire for a few years. At last yielding to the unabating efforts of chemical affinity, the most beautiful face loses its youthful glow, and the speaking eye loses its brilliancy. They are given over to form the constituent elements of sulphuretted hydrogen, carburetted hydrogen, ammonia, carbonic acid, and other inorganic substances. What now constitutes the symmetry and all the fascinations of beauty, may be

converted into the various gases; which, after floating a while at the pleasure of the winds, are absorbed by the earth, and re-appear in the form of a rose, an ear of corn, or the deadly nightshade. The well known fact, that the living principle is at variance with the laws of matter, demonstrates conclusively that every living being, whether animal or vegetable, is essentially composed of matter, and of a substance distinct from matter. The existence of one substance being proved, with properties not only distinct from matter but directly opposed to the laws of matter, completely overthrows every argument of the materialist. For after the existence of one immaterial substance is proved by sensible properties, the existence of another may be reasonably inferred from its properties also. Therefore the faculty of thinking points to an intellectual substance; though its existence has not been demonstrated by actual experiment, like that of the living principle.

VEGETABLE SUBSTANCES.

ULTIMATE ELEMENTS.

Vegetable matter is essentially composed of carbon, oxygen and hydrogen.

The cruciform family of plants, such as cabbage, mustard, radishes, &c. contain a little nitrogen. In some few plants, sulphur has been detected. Potash, lime, soda, magnesia, and silex, have been found in plants.

When vegetable matter is heated in a retort to that degree which is called destructive distillation, the constituent elements assume new arrange-

ments; and carbonic acid, carbonic oxid, carburretted hydrogen, empyneumatic oil, water, &c. come over, leaving charcoal, and generally some earths and salts, in the retort.

After these products are separated, each is analyzed. From the result of these analyses, the proportions of carbon, oxygen and hydrogen are ascertained. Or if we rely upon the analyses of these products, which have been made by chemists, we have only to ascertain the proportions of these products to be enabled to calculate the quantity of the ultimate elements contained in any vegetable substance under examination.

PROXIMATE ELEMENTS.

These elements may be distributed into five divisions by a trial of their solubility.

Illustration. Dissolve, or attempt to dissolve, one or more of the elements of each division; if the solution is made, precipitate it by adding an excess of a substance which is not its solvent.

Application. When any of the proximate elements, enumerated below, are to be used, let them be brought to the liquid state, or precipitated, as their application may require.

First Division.

Proximate elements, which are soluble in cold water.

Acids, sugar, gum, jelly, colouring principle, bitter principle, nicotin, extractive matter, emetin.

Second Division.

Proximate elements, which are insoluble in cold water, but partially soluble in hot water.

Morphia, cerasin, starch, indigo, gluten, plecten, fibrin.

Third Division.

Proximate elements which are insoluble in water and melt and burn when heated. Most of them are soluble in alcohol.

Fixed oil, wax, volatile oil, camphor, resin, guaiacum, balsam, gum-resin, caoutchouc, bitumen.

Fourth Division.

Proximate elements, which are not soluble either in water, alcohol, or ether; having a fibrous or woody texture.

Cotton, cork, pitch, wood, fungus.

Fifth Division.

Extraneous substances sometimes found in vegetables.

Mineral acids, alkalies, earths, metals.

DISTINCTIVE CHARACTERS.

First Division.

Acids.

Acetic acid is distinguished by the well known odour of vinegar. It is generally produced by fermentation from wine, cider, &c. But it is found ready made in the fruit of *rhus typhinum* and some other plants.

Oxalic acid decomposes all salts of lime. It is found in the *oxalis stricta*, and other plants. Heat destroys it.

Tartaric acid forms the common tartar if a little potash is dropped cautiously into a solution of it.

It is found in *rhus typhinum*, *oxycoccus*, &c. But is generally obtained from the lees of wine. Heat destroys it.

Citric acid does not form tartar with potash. It is found in the juice of oranges, lemons, in *oxycoccus*, &c. Heat destroys it.

Malic acid does not form tartar with potash, and it forms a salt with lime, which is soluble in water and decomposed by citric acid. It is found in green sour apples, the barberry, &c.

Benzoic acid is volatile in moderate heat and is aromatic. It is found in the styrax tree chiefly ; but it is also found in the *laurus benzoin*, *origanum majorana*, &c.

Prussic acid forms the prussian blue when poured into a solution of copperas. It is found in peach meats and blossoms, &c. It is called the *hydrocyanic acid* by some chemists. See this article under animal substances, from which it is obtained for use in the arts.

Kinic acid, on burning coals, froths, melts and turns black, and finally is exhaled in acid vapour. It does not precipitate nitrate of mercury or silver. It is obtained from Peruvian bark.

Gallic acid produces a black colour with the oxid of iron. It is found chiefly in most species of oak ; but many other trees contain it also.

Tannin unites with a solution of animal jelly (rather prefers the isinglass) and forms a dense precipitate. It is found in every species of oak, and in the *pinus canadensis*. It is most abundant in the bark of trees.

Its use in the manufacture of leather depends on its affinity for animal gelatin.

Sugar dissolves rapidly in water, more especially if heated, and dissolves slowly in alcohol.

It is combustible, and, when mixed with oxymuriate of potash, if a little sulphuric acid be applied, it burns spontaneously.

Sugar preserves fruits from putrefaction, but tends to promote the decay of human teeth. It is nutritive as a diet, and assimilates kindly with human fluids.

It is chiefly obtained from the common sugar cane and the sugar maple. It may be obtained from the stalks of indian corn, pumpkins, beets, &c.

Sugar is purified by boiling with blood of cattle, which brings to the surface all impurities. By heating sugar with nitric acid, oxalic acid is formed. Alkalies in solution mixed with sugar in solution, destroy its sweetness; which is restored by a due portion of acid. Consists of 51.3 oxygen, 6.8 hydrogen, 41.9 carbon.

Gum is highly soluble in water, forming a mucilage; but is insoluble in alcohol. Gum is converted into citric acid, by chlorine. It oozes from wounds in cherry trees, peach trees, &c. Some of the chief gums of commerce are gum arabic and gum senegal.

Jelly is scarcely soluble in cold water. It readily assumes a kind of half coagulated tremulous state. It exists in currants, gooseberries and many other fruits.

Colouring principle is found in many of the proximate elements of vegetables. The logwood, nickaragua, madder, &c. of the shops are well known. We find it abundant in the common butternut tree, the walnut tree, &c. Most vegetable colouring materials require a mordant to fix the colouring in the stuffs; some of which fix the col-

our without change, others produce a change in the colour.

Bitter principle is known by the taste. It is generally very soluble in water or alcohol. It is generally precipitated by nitrate of silver and by acetate of lead. It is found in numerous vegetables.

Extractive principle is chiefly applied to all substances which are extracted from plants by the aid of water and remain in the state of a dry mass after the water is evaporated. Therefore sugar, liquorice, gum, jelly, &c. are included in it. But Thompson proposes a more narrow and more definite limit to the term.

Emitin is supposed to be a peculiar principle in ipecacuanha and most other plants, which cause the stomach to throw up its contents.

Second Division.

Morphia, a principle contained in the poppy and some other plants, which induces sleep.

Cerasin is a principle which has been confounded with the gums. But it differs from gum in swelling and becoming transparent in cold water, without actually becoming dissolved until the water is heated. The gum tragacanth is pure cerasin.

Starch, though it does not dissolve in cold water, it falls into powder. With boiling water it forms a kind of jelly. It does not even fall into powder in alcohol. When dried it becomes a white brittle mass.

Starch may be washed from its connection with gluten in wheat flour in cold water, from which it will soon settle in the state of powder. It is obtained from potatoes also and numerous other vegetables.

Gluten forms with water a soft tenaceous ductile paste. It may be obtained almost pure by making bakers' dough in the usual way, and then washing it in cold water, until the water comes off clear. The starch being extricated in this manner, the remainder will be nearly pure gluten. Gluten, like animal gelatin, is precipitated from its solution in water by an infusion of galls.

Indigo is scarcely soluble in hot water, but dissolves in alkaline leys and becomes reddish. The pure colouring matter of indigo does not exceed 47 per cent. The other constituents are separated by 1st water, 2d alcohol, 3d muriatic acid. These several solutions being poured off and the sediment washed in succession, the last sediment is the pure colouring matter, and burns with a purple smoke.

Fibrin, which will be mentioned under animal matter, has been detected in the juice of the papaw tree in Peru. Nothing short of the authority of Vauquelin could commend our belief in such a remarkable case.

Third Division.

Wax.—Vegetable wax is found on the surface of the fruit of the bay-berry, (*Myrica cerifera*.) Bees-wax is also a very perfect vegetable wax, when purified and in the state of white wax. It is soluble in heated fixed oils, when it forms the cerates of physicians. Some of the volatile oils dissolve it also. It is soluble in potash and soda, forming a soap-like compound. It is not much affected by acids; therefore it is useful in etching, luting, &c.

Fixed Oils. Vegetable fixed oil is pressed from the flax seed in large quantities ; and is much used by painters. Castor oil, which is pressed from the castor bean (*Ricinus communis*,) is used in medicine. Fixed vegetable oil may be pressed from the fruit of the walnut, butternut, &c. Olive oil is also an important fixed oil. A fixed oil may be separated into the concrete part, (*stearine*) and the fluid part (*elaine*.) And they are more or less inclined to retain the liquid state, according to the proportion of *elaine* contained in them.

Some oils readily become hard and resinous on exposure. These are called *drying oils*. They are used in the manufacture of printer's ink. It is pretty highly heated, set on fire and burned about half an hour, then extinguished and boiled down until it is of a suitable consistency. Afterwards it is mixed with some spirits of turpentine and lamp black. Nut oil is preferred for printer's ink ; but linseed oil is often used.

Fixed vegetable oils combine with the alkalies and form soap. The best hard soap made is of olive oil and soda.

Volatile Oils. These oils are very numerous. They are distinguished from fixed oils by being converted into a state of vapour by heat ; whereas fixed oils cannot be evaporized or volatilized without combustion, and, of course, decomposition. Some of the most common volatile oils are, spirits of turpentine, oil of lemons, juniper, rosemary, tansy, wintergreen, mint, (called pepper-mint essence,) pennyroyal, fennel, cloves, cinnamon, aniseed, dill, &c. They are highly soluble in alcohol, but hardly soluble in water. They are mostly obtained by steeping vegetables in wa-

ter, and then distilling over in common stills. They are generally called essences, because they contain the essence of the sensible qualities of the vegetable.

The volatile oils become thick and somewhat resinous by the absorption of oxygen on long exposure to air. It is probable that volatile oils become indurated and give strength and durability to the woody fibre by drying. For when timber is water-seasoned, as it is called, (that is soaked in water awhile and then dried to prevent its shrinking,) it is more easily broken and decays sooner. Wood is found to be less valuable as fuel, which is cut down while green and exposed to rains. In both cases the volatile oil is extracted more or less by water. It is therefore better for fuel or timber when it is cut down in a green thrifty state and dried or seasoned under a shelter. If a volatile oil is adulterated by a fixed oil, it may be detected by rubbing a little of it on paper, and holding it near the fire. The volatile oil will evaporate and leave a greasy spot on the paper, which is made by the fixed oil. The essence-pedlers generally purchase a small quantity of the volatile oils, and then adulterate largely with alcohol. This is a very common fraud, and ought to be detected and exposed, which may be done by pouring a few drops into a wine-glass of water. The pure essence will float on the water, and scarcely mix with it at all. But if it is adulterated with alcohol, it will mix with the water, and a change in colour, &c. will instantly appear.

Camphor. This substance is obtained from the camphor tree of Japan, (*Laurus camphora*.)—This is a species of the same genus with the sassa-

frass and spice-bush of our country. And the camphor has many properties in common with the volatile oil of sassafras and other vegetables. It is soluble in alcohol and hardly soluble in water ; it dissolves in both the fixed and volatile oils.

Camphor may be made artificially. At least a substance is deposited very similar to camphor, by passing a current of muriatic acid gas through spirits of turpentine.

Resins. The juice which exudes from the white pine, and several other species of the genus *pinus*, consists of the resin and the volatile oil, called spirits of turpentine. By distilling over the latter, the former remains pretty pure.

Pure resin is insoluble in water, soluble in alcohol and the alkalies, and almost devoid of taste or smell. Those which do give off an odour, are combined with volatile oil ; and are generally denominated *balsams*. Besides those resins which come under the general denomination of pitch, are the guaiacum, copal, mastich and others ; the two last of which are hardly soluble in alcohol. There are several hard resins, called *lac*, which are deposited by an insect in the East Indies, on twigs of trees, &c. the most common of these is called shell-lac.

There are compounds of gum and resin, called *gum-resins*. Gamboge and assafoetida are of this kind. As gum is soluble in water and resin in alcohol, it requires both for their solution. *Ambur* is placed under resins ; but it is hardly soluble in alcohol or in the alkalies.

Caoutchouc. This substance is generally called *india rubber*. It is manufactured by drying the juice of an East India plant, called the *Urceola elastica*, according to Sprengel and Roxburgh.

It is also obtained from a South-American plant, called *Siphonia elastica* by Linneus ; Lamarck calls it *Hevea guianensis*. Both of these plants belong to the same natural order with our common milk-weed (*Asclepias syriacus*,) and the juice of the milk-weed, when dried, resembles the india rubber. It is very elastic and inflammable. It contains nitrogen. It is insoluble in water ; but may be softened and rendered very adhesive in hot water, so as to be made into flexible tubes by winding slips of it spirally around small cylinders and uniting the edges.

Bitumen. This substance partakes something of the nature of oils and resin. When pure, it is a limpid liquid, and is then called *naphtha*. It consists of about 87 per cent carbon, and 13 per cent hydrogen. As it contains no oxygen, the inflammable bases of potash, &c. are kept in it.—When in the state of a brownish iridescent liquid, as it is seen floating on stagnant waters, it is called *petroleum*. When in the solid state, as it is found in Trinidad, and on the shores of Lake Asphaltides, it is called *asphalt*.

PRODUCTS OF FERMENTATION.

Some vegetable solutions will undergo spontaneous changes, whereby alcohol or vinegar is produced ; during this process carbonic acid gas is evolved.

Illustration. Put some sugar into a florence flask, and dissolve it with about five times as much warm water, and add a little yeast. Set it where it will continue to be warm, but not hot. Let one end of a bent lead or glass tube be fitted into the flask by perforating a sound cork, and let

the other end pass under the moveable shelf of the cistern. After standing awhile, a gas will begin to come over.—As soon as the atmospheric air has passed out, begin to collect the gas. On testing it with lime water, it will be found to be carbonic acid gas.

Application. From this experiment it appears, that sugar alone is sufficient to produce fermentation with water, when started with yeast. It is found that sugar is essential by many trials. This is the same gas which issues from cider, beer, &c. when fermenting—it is also produced in dough when rising.

The intoxicating substance called alcohol, is produced during fermentation. Alcohol being converted into vapour with less heat than water, it may be distilled over by a due degree of heat. Thus rum, brandy, gin, cider-brand, &c. are obtained.

Cider is sometimes boiled down for family use ; as for making apple preserves, &c. This should always be done before fermentation commences ; because alcohol will then be formed, which will be driven off and wasted by evaporation, while boiling down the cider.

The ardent spirits of commerce consist of alcohol combined with water, and some other adulterating substances, giving each kind its peculiar flavour ; from either of which pure alcohol may be obtained by re-distillation, and the absorbing power of potash.

Illustration. Fill a pint retort half full of common proof whiskey. Fit the beak to a receiver and surround the neck with beeswax where it enters the receiver ; so that if water is applied to

the neck of the retort it cannot run into the receiver. Let the receiver be immersed in cold water, or surrounded with snow. Set the retort into the lead pot over coals in the usual way, and raise the heat by the hand bellows. Set the lead pot so near the cistern, that cold water may be poured on the neck of the retort and be renewed in the vessel where the receiver is immersed, without wetting the room. Alcohol will rise up in vapour and be condensed in the neck of the retort, and run down into the receiver. After the measure of the alcohol in the receiver about equals the measure of what remains in the retort, stop the process.

Put into a tumbler a quantity of pearlash, about equal in weight to one fourth of the alcohol distilled over, which had been made as dry as possible on a plate exposed to a little heat, let the pearlash be warm as can be borne by the hand when put into the tumbler, and pour the alcohol upon it. Stir it up and keep the alcohol in the tumbler with it, about half an hour. Now let it settle and pour out the alcohol for use.

Application. By this method very pure alcohol may be obtained. On the same principle, with large retorts and receivers, alcohol may be obtained for the use of the physicians and the artist. If carefully distilled and well prepared, it will be so inflammable that if it be poured upon an earthen plate with good gun-powder on the bottom, it will burn down and inflame the powder.

Alcohol has such a strong affinity for water, that on mixing them they unite so closely as to diminish their measure, or volume.

Illustration. Fill the bulb of a bolt-head, or long-necked matrass, with water. Incline it a little, and pour in alcohol to fill the neck almost full. Let it glide down slowly along the inside of the neck, so that it may chiefly float on the surface of the water. Having previously tied a piece of a thread around the neck, slide it to the precise level of the surface of the alcohol. Now put the thumb over the mouth of the bolt-head, and shake it so as to mix the two liquids. It will now be seen that the surface of the combined liquids is considerably lower than the thread.

Application. This diminution of the measure of the liquids encreases their specific gravity. Consequently the reduction of alcohol by water is indicated directly by the increase of the specific gravity. When perfectly pure the specific gravity of alcohol is 0.79, but it can hardly be obtained below 0.82. Pure alcohol consists of 34.32 oxygen, 13.70 hydrogen, and 51.98 carbon.

Alcohol, boiled with sulphuric acid, produces a light volatile compound, called ether.

Illustration. Having fitted the beak of a retort to a tubulated receiver, as directed in obtaining alcohol, immerse the receiver in cold water, or surround it with ice. Raise the heat in the lead pot considerably; but do not put in the retort yet. Put some alcohol into a tumbler, and add the same weight (or a little more than half the bulk) of sulphuric acid. The acid must be poured in gradually, and well stirred, as it drops in, with a glass rod. If it is poured in fast it will become too hot; but it must not be so hot that the heat of the tumbler cannot be borne by the hand. As soon as it is mixed, set the retort into the lead pot, and immerse

diately pour into it the mixed liquids through the tubulature, and put in the stopper. Raise the heat to a little below the boiling point of water immediately, and keep it at that temperature.—This may be determined by frequently dipping a small stick into hot water, and touching it to the hottest part of the retort. It must not be quite hissing hot. If the stick is dipped into cold water it may break the retort.

Continue the process until the whole liquid in the retort begins to rise up. Then either stop the process, or pour in half as much alcohol as at first, and more may be brought over. If the vapour presses too hard during the process, open the tubulature of the receiver an instant, occasionally.

Application. By adopting this method of preparing ether, with large retorts and receivers, physicians and artists may prepare the best of sulphuric ether, and thereby avoid both expense and imposition.

Ether is extremely volatile ; so that if a part of the atmospheric pressure is taken off, it will boil with the warmth of the hand.

Illustration. Put a little ether into a long-necked vial (a cologne vial is best.) Heat the vial so that it can hardly be borne by the hand, while its mouth is open. Then put in the cork perfectly tight. Now if a warm hand be clasped around the neck of the vial, and it be held with the bottom up, the ether will boil.

Application. This experiment is an additional confirmation of the principle given under Caloric, p. 30. It exhibits the volatile nature of ether also, upon which much of its usefulness depends.

Fermented liquids which produce alcohol will undergo a second fermentation, if exposed to warm atmospheric air ; in which state the alcohol will be destroyed and vinegar will be produced.

Illustration. Expose a little cider, strong beer, or wine, to a summer's sun, or to the air of a warm room in an open bowl or an earthen plate, and in a few days, or sometimes in a few hours, it will become acetous, and lose all its alcoholic principle.

Application. Upon this principle common vinegar is made. Oxygen is absorbed from the atmosphere, which is supposed to unite with and carry off another proportion of carbon in the state of carbonic acid gas. Pure acetic acid consists of 46.82 oxygen, 6.35 hydrogen, 48.83 carbon.

If good sound wood be heated in a confined situation, as in a gun-barrel, &c. the *pyroligneous* acid comes over, which makes good vinegar when separated from several impurities which come over with it. Vast quantities of this acid are produced in the manufacture of charcoal for making gun-powder.

Acetic acid, the pure basis of vinegar, is best obtained by combining common vinegar with the oxid of a metal, forming a salt, as acetate of copper (verdegris) acetate of lead, (sugar of lead) and then distilling it over by heating the salt to redness.

When wine becomes partly acetous, called pricked wine, the disagreeable taste is often corrected by sugar of lead. It is then poisonous, and the fraud ought to be detected. This may be done by dropping it into a little water, charged with sulphuretted hydrogen gas. It will immediately become dark brown.

ANIMAL SUBSTANCES.

ULTIMATE ELEMENTS.

The essential ultimate elements of animal substances are, carbon, oxygen, hydrogen and nitrogen. Generally sulphur and phosphorus are found in animal matter.

The addition of *nitrogen* causes the most important distinctions between animal and vegetable substances. It being one of the constituents of ammonia, it gives rise to that gas, during the decomposition of animals, by the process called putrefaction. Several other substances are frequently found in animal matter ; as, oxid of iron, lime, soda, potash, &c.

PROXIMATE ELEMENTS.

The most important proximate elements of animal substances are, gelatine, albumen, fibrin and oil.

Gelatine. This substance is commonly seen in the form of *glue* and *isinglass*. Gelatine constitutes a large proportion of the skins of animals, &c. It has a strong affinity for tannin. This will appear by dropping an infusion of tannin (from common nut-galls will do) into a solution of isinglass. A pretty solid precipitate will be formed of the union of tannin and gelatine. On this principle leather is formed ; the gelatine of skins combining with the infusion of tannin obtained by soaking bark in water. It is not coagulated by sulphuric acid diluted.

Albumen. This substance is the most distinctly exhibited in the *white* of eggs. It always con-

tains so much soda as to give the alkaline test with red cabbage. This may be shown by dissolving it in pure water, and dropping in the infusion of red cabbage, which will give the green test of alkalies. It is immediately coagulated, and at length charred by sulphuric acid.

Fibrin. The constituent of the fibrous part of muscles, &c. Fibrin and albumen are the principle constituents of blood. If a stream of blood from a vein runs through a fine camel-hair brush, fine fibres may be seen attached to the hairs, after the red globules have been carefully soaked off.

Oil. This appears in the form of lard, tallow, spermaceti, &c. It is divided into the *stearine* and *elaine* parts like fixed vegetable oil. Oil and albumen are the principal constituents of milk. It is slowly soluble in alcohol and not precipitated by water.

Remark. Several more proximate elements are described by chemists, but they are of little importance to those for whom this work is intended.

BONES AND SHELLS.

Internal bones of animals consist mostly of phosphate of lime. They contain a little carbonate of lime and some animal matter.

External shells of animals are chiefly carbonate of lime. They generally contain a little phosphate of lime, and some animal matter. Those animals which are covered with an external crust, as the lobster, &c. have their covering chiefly made up of nearly equal proportions of carbonate of lime and phosphate of lime, which contains a larger proportion of animal matter.

RESPIRATION.

Oxygen changes the dark colour of blood of the veins, to the scarlet colour of arterial blood.

Illustration. Drop a small mass of dark clotted blood into a vial of carbonic acid gas, and another mass into a vial of oxygen. Place the fingers over the mouth of each, and shake them pretty hard. The blood in the oxygen will become scarlet coloured, while that in the carbonic acid will remain dark coloured. If atmospheric air is now substituted for oxygen, and another portion put in, it will become scarlet coloured, but not so bright.

Application. It appears from this experiment, that oxygen may affect the blood in respiration, so as to produce the necessary change required (at least in the colour) for rendering it a fit material for supplying the waste of the system.

Atmospheric air suffers a diminution of bulk by respiration ; and the oxygen is consumed, or diminished in quantity.

Illustration. Put a mouse into a glass cylinder, and invert it over mercury, pressing it down into the mercury for a few minutes at first, so that the pressure of the mercury may prevent the escape of air by the warmth of the mouse. Let the mouse remain until it expires ; which will be in about half an hour in a half pint cylinder. The mercury will now be found to have ascended a little in the cylinder. If great exactness is required, let the temperature be regulated by the thermometer ; so that the operator may be certain, that the air is not more expanded when the mouse is put in than afterwards.

Now take out the mouse through the mercury, fill a slender tube or test glass with mercury and pour up the contents of the cylinder into it. Turn the open end upwards and hold the finger on it two or three minutes. The gases within it will separate. Carbonic acid will settle at the bottom, and nitrogen will rise towards the top. This may be proved by immersing in the top only, a small burning taper. It will be extinguished two or three times, and afterwards will continue to burn near the top. Let it now stand open several minutes, and then immerse the taper to the bottom and it will be extinguished. The nitrogen being lighter than atmospheric air ascends, and atmospheric air takes its place; but carbonic acid being heavier remains at the bottom.

Application. Several important principles are illustrated by this experiment. A crowded assembly in a close room consume the oxygen and give off carbonic acid gas. The excess of nitrogen ascends to the upper ceiling, while the carbonic acid settles down near the floor. Consequently the purest air, or that which contains most oxygen, is between the two.

The diminution of the bulk of air in the cylinder is a strong argument against a late theory of Allen and Pepys respecting respiration. The old theory, which this experiment seems to support in some measure, supposes the change produced in the blood to be caused by an additional portion of oxygen, which is received from the inhaled air, through the thin membranes of the lungs. The theory of Allen and Pepys supposes the blood to be decarbonated, by the union of a portion of carbon given off in the lungs with oxygen of the in-

haled air. But this theory requires that the bulk of the air in the glass cylinder should neither be increased nor diminished. For the addition of carbon, in forming carbonic acid, although it increases the specific gravity, does not increase nor diminish the bulk of the gas. See illustration at pages 107 and 108.

Animal effluvia, arising from the beds of the sick or from other sources, may be neutralized by the strong acids in the state of gas.

Illustration. It seems to be proved by observation that such effluvia are combined with aqueous vapour. The ready union of aqueous vapour and the strong acids in the state of gas will appear by first pouring a tea-spoon of muriatic acid upon a red hot iron shovel, and then pouring a wine-glass of water upon it. The acid will rise up in the state of a suffocating gas, and the water will follow it in the state of vapour and absorb it almost instantaneously, so that the suffocating gas will wholly disappear.

Application. Contagious vapour arising from the beds of the sick, the marsh miasmata (carburated hydrogen combined with aqueous vapour) and other pestilential effluvia, may be neutralized as follows: Remove the sick and other persons from the room. Set a tea-cup or gallipot on the floor, half filled with table salt. Pour into it strong sulphuric acid, and the room will be filled with muriatic acid gas. After a few minutes open the windows, and the air of the room will be purified.

ACIDS.

Animal matter highly heated in contact with potash will yield the prussic acid, (the most active of

all known poisons) and the prussiate of potash will be formed.

Illustration. Put some shavings of hides, which may be procured at the tanners, into a crucible, and invert another crucible over it, as directed at page 102. Heat it until it becomes considerably charred; then take it out and reduce it to a coarse powder. Boil some potash in a ladle and continue the heat until the potash is reduced to a dry granulated mass. Mix the two substances in about equal parts, and heat the mixture in a ladle pretty closely covered with a sheet of iron. Raise the heat until the blaze which leaks out under the cover becomes whitish or nearly colourless. Now pour this mass into boiling water, and continue the heat some time. Skim off all carbonaceous and other substances which rise to the surface. When no more rises, stop the heat. This is the liquid prussiate of potash. It may be evaporated and form imperfect crystals.

Application. This is the most delicate test for detecting the presence of iron. But the experiment is difficult to be performed before a class, and hardly to be recommended. Prussiate of potash may be purchased of the druggists.

A solution of the prussiate of potash will form the prussiate of iron (prussian blue) by double decomposition with a solution of sulphate of iron.

Illustration. Dissolve some copperas in a wine-glass, and an extremely small piece of prussiate of potash in another. Put a drop of the solution of prussiate of potash into the copperas, and a prussian blue precipitate will be formed.

Application. On the principle of the two last

experiments, the prussian blue is manufactured in the large way.

Prussiate of potash may be decomposed and prussiate of mercury formed, by boiling it with nitric oxid of mercury, (red precipitate.)

Illustration. Pulverize some common prussian blue and put it into a florence flask. Put in about half and one eighth as much red precipitate. Then pour in about three times as much pure water (calling a pint a pound) as of the prussian blue; and boil the mixture until the red precipitate entirely disappears. This will produce the prussiate of mercury in the liquid state. It may be strained through paper, and about one fourth as much boiling water as was put in at first may be added.

Application. This salt is not much used, excepting for the purpose of procuring pure prussic acid. For this use it is best to keep it in the liquid state, as above directed to be made, closely corked up in vials.

Prussic acid may be obtained from the prussiate of mercury by heat.

Illustration. Fit a long-necked tubulated retort to a tubulated receiver. Surround the receiver with snow or ice, and set the retort into the lead pot in which the coals are but very little heated. Pour into the retort some of the liquid prussiate of mercury prepared as above, through the tubulature. Pour about one eighth part as much pure water through the tubulature into the receiver; and fit a waste pipe into the tubulature which may conduct off, into water or elsewhere out of the way, hydrogen and any other offensive gas which may arise.

In order duly to regulate the heat, &c. now put into the retort through the tubulature about half as much by weight of pure fine iron filings, as was used of the prussian blue. All being ready, now pour in as much strong sulphuric acid by weight as of the iron filings, and instantly wring in the glass stopper very tight. Blow very lightly into the air hole of the lead pot with the hand bellows, so as to raise the heat a little; but not so as to boil nor even to simmer the liquid. Hydrogen gas will pass into the receiver and out at the waste pipe. The prussic acid will come over in a state of vapour, and being condensed by the cold of the ice, &c. will run down and unite with the water in the receiver. After it appears that about two thirds as much liquid is in the receiver as would equal the weight of the prussian blue (calling a pint of the liquid a pound) stop the process, cork up the prussic acid in vials and put it into a dark cellar, which is cool in summer and warm in winter.

Application. This substance is lately used in consumptive cases. Two or three drops are diluted in a large quantity of water. It is the most active narcotic known. Two or three drops on a large dog's tongue or in the corner of its eye, will kill it in one or two seconds. It is too dangerous an article to make or to use before a class. Let it be described to the class; but it should be made in the private office only. A small quantity is found in the meats of almonds, peach stones, cherry bark, the *laurus cerasus*, &c. And the scent of the prussic acid considerably resembles the odour of these vegetables.

Some chemists place this substance among the vegetable acids, because it is found in vegetables

and not in animals. Since it is produced from animal substance I have placed it here ; though I do not contend for the propriety of this location.

The basis of this acid is found by Gay Lussac to consist of carbon and nitrogen. It is the carburet of nitrogen, by some called *cyanogen*.

Remark. The remaining animal acids, enumerated by authors, are of little use ; and many of them are not well defined. That which is most worthy of the particular attention of the house-keeper is the

Sebacic acid. It is this acid which is so readily produced by butter or fat, giving it a disagreeable rancid flavour. Butter with this flavour is called frowy butter in New-England. This acid may be neutralized by any of the alkalies. Pearl-ash or carbonate of soda will do it effectually. If a little pearlash be dissolved in water, and the butter be worked over with this water, all the sebacic acid will combine with the potash and form a soluble salt. If the butter is then worked over two or three times with pure water, the sebaceate of potash as well as the pearlash will be worked out, leaving the butter pure.

If cakes, &c. be shortened, in the language of cooks, with frowy butter, and pearlash be added, the sebacic acid will decompose some of the pearlash, and thereby furnish carbonic acid to assist in raising the dough. This is the best method of using rancid butter or fat. Because the alkali may sometimes be tasted after it has been applied for cleansing as before described ; but when used for shortening, it cannot.

DYING.

Dying materials are either *substantive* or *adjective*.

Substantive colouring matters are those which may be made permanent upon stuffs without a mordant; as indigo.

Adjective colouring matters are those which cannot be made permanent without the aid of a mordant; as butternut bark, logwood, &c.

Mordants are the mediating substances, which are used for fixing adjective colours; as copperas, alum, muriate of tin, &c.

Some colouring matters produce different colours when a mordant is used; others are merely fixed by a mordant without any change in colour.

Dying is too extensive a subject to be presented in detail, in this Instructor. A few principles may be explained which will prepare the student for pursuing the subject under the head,

CALICO PRINTING.

Remarks. In the most simple operations, colouring matters and mordants are applied several times in succession, giving a different colour at every application. These applications are made with carved blocks, (mostly cylindrical) or by the aid of a defensive coat of wax, or of some other material.

Illustration. Prepare madder dye in the common way—also a dye of walnut bark—also a dye of indigo. Cover parts of a piece of white cotton with melted white wax, and dip it into acetate of alumine. Then melt off the wax in hot water. Now dip it into the madder dye. Then wash and bleach it. The dye will not take where the mordant was kept off by the wax.

Similar experiments may be performed with all other colouring matters, using acetate of alumine, sulphate of iron, acetate of iron, &c. Spots may

be made of different colours by applying a mordant, mixed with paste, by means of carving upon a block.

N. B. The teacher should put large treatises into the hands of students, if time will allow a full course ; as Bancroft, Cooper, &c. For very minute descriptions of particular manipulations being necessary, large systems must be consulted.

ANALYSIS,

OF MINERAL WATERS, SOILS, AND MINERALS.

Remarks. To analyze expertly and accurately requires the practice of several years, and an extensive collection of the most perfect tests.—The presence of common metals may be detected, without much difficulty. The substances which are usually held in solution in the mineral waters of our country, may be ascertained without a laborious process. But to determine the proportions of the parts of a compound mineral, or the quantity of any substance contained in mineral waters, requires in some cases, more practical instruction than can be communicated in the course here proposed.

The directions, which are given under this head, are sufficient for ordinary cases in the analysis of mineral waters—they are still more complete for the analysis of soils—but the analysis of the substances, which belong to the classes Metalloids and Metals, requires an extensive treatise. A mere outline is given here.

GENERAL TESTS FOR MINERAL WATERS, SOILS AND MINERALS.

As the hydro-sulphuret of ammonia will precipi-

tate the oxids of all metals, which form the basis of salts, the colours of the precipitates may assist in detecting metals.

Illustration. Put very dilute solutions of several metallic salts (as copperas, blue vitriol, white vitriol, sugar of lead, lunar caustic, &c.) into separate wine-glasses, and pour in an extremely small quantity of hydro-sulphuret of ammonia into each, and observe the different coloured precipitates.

Application. Dissolve a supposed metal in an acid—as sulphuric, muriatic, nitric or nitro-muriatic. Prepare a solution of a known metallic salt, as before directed, having a base of that metal which is suspected to be under examination. Pour some hydro-sulphuret of ammonia into both, and compare the colours, densities and other characters of the precipitate. Although this will not always afford conclusive evidence, it will assist in directing the judgment.

An infusion of galls will precipitate the oxids of many of the metals, which form the bases of salts; and the colours of the precipitates may assist in detecting such metals.

Illustration. Rasp off a quantity of nut-gall and soak it an hour or two in pure water. Strain off the liquid and put it into a phial for use. Dissolve several metallic salts as directed in the last experiment, and precipitate the oxids of the metals from their acids with the infusion of the nut-galls, and observe the colours of the precipitates.

Application. Metals may be tested by being reduced to salts and by collateral or comparison experiments as directed when using the hydro-sulphuret of ammonia. It must be understood, that the same metal sometimes gives different coloured

precipitates, when in different degrees of oxidation. The following are some of the colours as taken from Brande. With the proto-muriate of *manganese*, dirty yellow—proto-sulphate of *iron*, purple—permuriate of *iron*, black—muriate of *tin*, dirty yellow—proto-muriate of *tin*, (acid) straw colour—per-muriate of *tin*, (acid) fawn colour—proto-muriate of *copper*, yellow brown—per-nitrate of *copper*, grass green—nitrate of *lead*, dingy yellow—tartrate of *antimony* and potash, straw colour—tartrate of *bismuth* and potash, yellow—sulphate of *uranium*, bluish black—muriate of *titanium*, (acid) brown—sulphate of *titanium*, blood red—white oxid of *arsenic*, scarcely changed—any salt of *molybdena*, brown—sulphate of *nickel*, green—proto-nitrate and per-nitrate of *mercury*, (acid) yellow—nitrate of *silver*, curdy becoming brown—muriate of *platina*, brownish green—muriate of *gold*, wine colour.

Though the alkalies will take the acids from metallic oxids generally ; yet the metallic oxid will take metallic acids from the alkalies.

Illustration. Pour a solution of chromate of potash into solutions of several metallic salts, and chromates of the metallic oxids of the salts will be produced.

Application. Proceed as directed under hydro-sulphuret of ammonia, and much may be learned respecting the presence of metals. No precipitates of different metals will be of a similar colour. That of mercury will be cinnabar ; of silver, carmine red ; of lead, orange yellow, &c.

Several acids, alkalies, and salts, give evidence of the presence of mineral substances ; and thereby direct the student in the analysis.

Prussiate of potash gives the prussian blue precipitate with iron.

Muriatic acid gives the grey precipitate with silver.

Cochineal in solution gives a scarlet colour to muriate of tin.

Sulphuric acid will cause an escape of bubbles of carbonic acid gas, if poured into carbonated water. It takes barytes from any other acid, by forming with it a dense grey precipitate.

Brazil wood becomes yellow with acids, and its original colour is restored by an alkali.

Nitrate of silver gives a dense grey cloud in any solution containing muriatic acid, whether free, or combined with a salifiable base. On exposure to the sun's rays, this grey cloud (precipitate) becomes blackened.

Infusion or tincture of red cabbage gives a red colour when an acid is free, or in excess, and a green colour when an alkali is free or in excess. The human breath, if introduced into the red cabbage infusions, gives a light red colour, on account of the carbonic acid manufactured in the lungs.

Red cabbage infusion gives a red colour to water charged with sulphuretted hydrogen gas. It will give the same colour to cider, wine, ale, &c. because they contain a free vegetable acid.

N. B. Red cabbage becomes blue by standing a few hours, if the water in which it is mashed is pure. Paper in half inch slips dipped in a strong infusion of red cabbage, is better adapted to such experiments than the liquid infusion. On dipping each slips of paper into the liquid to be tested, its acid or alkaline character is shewn by the colour of the slip of paper.

Turmeric infusion is changed from yellow to brick-red or orange, by alkalies, whether free or combined with an acid ; but it is not affected by carbonates of the alkaline, or other, earths.

Nitric acid will convert gum, sugar, mucilage, or jelly, into oxalic acid by long digestion with heat ; but heat produces no change upon resin.

It detects the presence of starch if the substances be digested several days ; for alcohol will then precipitate it.

It detects nitrogen in meat, &c. for if poured upon meat in a retort, the nitrogen will come over in a state of gas.

It is the only heavy acid which dissolves silver alone.

Muriatic acid always forms a white precipitate with silver or lead. The silver precipitate becomes black on exposure to air.

It produces chlorine gas with per-oxid of manganese, if sulphuric acid be added.

Tartaric acid when combined with potash, forming the tartrate of *potash*, gives a crystalline precipitate ; but if the basis is *soda* the liquid will remain limpid.

Oxalic acid (oxalate of ammonia is better) will always produce a dense cloud with lime, whether free or combined.

Muriate of ammonia gives a bright yellow (or a little orange) precipitate, with muriate of platina.

Corrosive sublimate gives a white flocculent precipitate with albumen.

Phosphate of soda is a good flux with the blow-pipe, when deprived of its water of crystallization by heat.

Lime water, perfectly limpid, gives a grey cloud with carbonic acid, in the state of gas or in water.

It gives a brick-dust like precipitate with corrosive sublimate. It decomposes salts of magnesia, with a grey precipitate.

Tannin forms a solid precipitate with animal gelatin.

Muriate of platina produces a yellow precipitate with all salts of potash ; but not with soda. But the solution must be strong, and contain no excess of acid.

Sulphate of iron (when perfectly green) produces a brown precipitate with any salt of gold in solution. It gives a dark purple, and at last black, with gallic acid.

Muriate of lime produces a white precipitate with oxalic, malic, and tartarous acid.

Benzoate of ammonia precipitates iron of a yellowish colour.

Tincture, or infusion, of galls produces a violet, and at last black, precipitate, with any solution of iron.

Liquid ammonia gives any solution of copper a blue colour. Partially precipitates salts of magnesia ; but not salts of lime.

Oxalate of ammonia produces a grey precipitate with any salt of lime.

Prussiate of potash forms a precipitate with all metals but platina and it alloys, gold, antimony, and tellurium. As no earthy salt is affected by it, this circumstance makes it an excellent test for discriminating between metallic and earthy salts.

Barytic water is a substitute for lime water in detecting the presence of carbonic acid. It is better than lime water.

Muriate of barytes forms a cloud with sulphuric acid in any state of combination.

Nitrate of barytes, same as muriate ; but is preferable in a few cases, when muriatic acid would embarrass further experiments.

Iodine gives a purple colour to starch.

Alcohol dissolves several proximate elements of vegetables, which water will not dissolve. See vegetable matter.

Metallic zinc precipitates lead, if there is a little excess of acid in the solution.

Metallic iron precipitates copper (as a knife blade, &c.) if there is a little excess of acid.

Metallic copper precipitates silver, if the acid is a little in excess.

Black flux and white flux are useful with the blow-pipe.

Asbestos fibres are useful for wrapping around minerals to be subjected to the blowpipe, for holding them steadily. Minute specimens may be fastened to the fibres with plastic clay.

Charcoal for the blowpipe is very useful. A mineral put into a hole made in the coal will melt sooner, than if exposed to the blowpipe in the common way.

ANALYSIS OF MINERAL WATERS.

The following directions will be sufficient for detecting those substances which most commonly occur, and in the largest proportions, in the United States. Prepare the following waters artificially, and test them before the class.

In searching for any of these substances, it will be advisable to use the test for that first which we have the most reason to expect.

MURIATE OF LIME. *Nitrate of silver* in solution dropped into the water gives a dense white

cloud if it contains muriatic acid. *Oxalic acid* gives a light white cloud, if it contains lime. Oxalate of ammonia is better.

SULPHURETTED HYDROGEN. *Acetate of lead* in solution is precipitated dark brown.

CARBONATE OF IRON. *Tincture of galls* gives a dark purple, and at length a brown colour, if it contains iron. *Boiling* will drive off the carbonic acid, so that after it has stood awhile the iron will be so completely precipitated, that the supernatant liquid will not give the test with the tincture of galls.

SULPHATE OF IRON. *Tincture of Galls* gives the dark colour both before and after boiling.

FREE CARBONIC ACID. *Lime water* gives a white cloud before boiling, but produces no effect after boiling.

SULPHATE OF MAGNESIA. *Muriate of barytes* gives a cloud, if water contains sulphuric acid. If *red cabbage* does not give the acid test, the sulphuric acid is combined with a base. If the *tincture of galls* and *oxalic acid* give no test of iron or lime, we may presume the base to be magnesia. To be more sure, evaporate the water by a very gradual heat, and taste the dried residuum. If it has a bitter taste, it will be a confirmation of the tests.

MURIATE OF SODA. Test the muriatic acid by *nitrate of silver*. If *oxalic acid* does not give the test of lime, evaporate it slowly to dryness and taste it. No one can mistake the taste of common salt.

Incompatible salts are often mentioned in books. But these incompatible salts often exist together while the water is cold; but as soon as the water is heated, decompositions take place.

The preceding are not given according to the nice directions of the books; but they will serve as a convenient guide.

If *lead* be suspected in water which has passed through leaden aqueducts, pass *sulphuretted hydrogen gas* into a portion of it, and if it contains lead, it will instantly exhibit a dark brown tinge.

If *copper* is suspected in water, or in any article of diet which has stood in a copper vessel, pour into it liquid ammonia, and it will become blue.

N. B. Always institute collateral experiments upon known substances, which are similar to those for which you are searching. In doing this, make use of very minute portions; because large quantities may alter the appearance.

When it is required merely to know whether the water is of that kind called hard-water, without regard to the kind of substances held in solution, dissolve a small piece of fine hard soap in alcohol, and pour a few drops of this solution into the water. If it is hard water it will become milky—if not, it will remain limpid.

ANALYSIS OF SOILS.

The object in analysing soils is not to ascertain the ultimate constituents of soils. It is to ascertain the constituents of soils, so far as such constituents have any influence upon the growth of plants. Such constituents may be,

1. Stones above the diameter of the fourth of an inch. These stones serve to prevent the soil from becoming too compact, and to retain moisture on their surfaces; and, in some cases, to condense floating vapour when at the surface of the soil.

2. Pebbles below the diameter of the fourth of an inch. These serve for most of the uses of stones; and, being of a more suitable size, are useful in keeping the soil in a kind of loose porous state, adapted to the extension of roots and transmission of moisture.

The constituent elements of stones or pebbles can have no influence on the productiveness of soils; unless reference is had to the future changes to be effected by their disintegration. A pebble of diamond, sapphire, or quartz, will have the same influence upon vegetation; though on an ultimate analysis the first would give carbon, the second alumine, and the third silex.

3. Siliceous soil. This has such a feeble attraction for water, that it will remain but a short time suspended in it. Such a soil scarcely suffers by a wet season, and does not suffer severely by a drought. It never "winter kills" wheat. But it is not a rich soil.

4. Alluminous soil. This is always in the state of an impalpable powder. It attracts water so strongly, that it will remain long suspended in water. Such a soil is too soft in a rainy season, and bakes hard in a dry season. It requires a due mixture with silicious soil.

5. Lime soil. A soil which abounds in carbonate of lime. This may be considered as a permanent manure. Its ultimate disintegration enriches soils.

6. Soluble salts. Most salts of this kind promote the speedy growth of plants. These, together with some insoluble salts, as gypsum, pulverized marble, &c. act as stimuli, and cause vegetables to seize greedily upon any nutriment with-

in their reach, as a glass of brandy excites strong appetite in a healthy labourer.

7. Animal and vegetable matter. The basis of these substances is chiefly carbon. But the whole, not only furnishes nutriment directly to plants, but absorbs from the atmosphere those gases which are highly nutritive to them. This has been shewn in the preceding part of this book.

8. Water. Some soils hold more water than others, between the drying heat of the sun and a heat sufficient to charr dry combustible vegetables. Such soils will resist the ill effects of a drought.

9. Oxid of iron. This is always found in soils; but its effects on vegetation seem not to be settled. It is probably useful.

10. Powers of retaining water, so as to remain mechanically suspended in it. This seems not to depend wholly on the proportion of the alumine. And when ever any soil, or any portion of it, will remain suspended in water over four hours, wheat sown in it is often "winter killed."

The following formula is an improvement, after five year's experience, upon one adopted by Dr. T. Romeyn Beck, and myself, in analyzing the soils of Albany and Rensselaer counties.

1. Several pounds of soil are weighed, which was taken from an average of the field. The stones are picked out and weighed, which are above the fourth of an inch in diameter, and their percentage estimated.

2. Six hundred grains of this soil is weighed out, after deducting the above percentage, and put into a pint of pure water, thoroughly stirred, and allowed to settle one minute. All above the sed-

iment of pebbles is then poured off. The pebbles are sun-dried, weighed, and their percentage estimated. What is poured off is sun-dried, and reduced to an impalpable powder in a clean Wedgewood mortar.

3. One third part is put into a crucible and heated gradually, constantly stirring it with a dry pine stick, until the stick becomes a little brownish from the heat, on pressing it against the bottom of the crucible.

4. It is then carefully poured into the scales and again weighed. What is deficient is set down as *water*.

5. The parcel is then returned into the crucible, and heated to a high red heat. It is frequently stirred with a glass rod, and the heat is continued until the mass presents no shining sparks. After allowing it to cool a little, it is returned into the scales again, and what it wants of its last weight, is set down for the *animal and vegetable matter*. Part of this remainder is undoubtedly water, but probably is not more than should always be considered as attached to this part. It may here be added, that there will be no blackness in the appearance of the soil, if it has been sufficiently heated.

6. Let it now be poured into an assay glass, and half a pint of pure water added to it. After repeated stirring for ten minutes, let it stand about three minutes to allow the siliceous matter to settle. Then pour off all which stands over the siliceous part into another glass. Dry this sediment in a high red heat, weigh it and set it down for the siliceous soil.

7. Let the part which was transferred to another glass, stand until it settles, leaving the liquid clear.

Pour off the liquid into another glass, dry this sediment with a high red heat, weigh it, and set it down for the *aluminous soil*.

8. The remaining liquid is then evaporated in a glass evaporating dish. The solid residuum is scraped off, and weighed for *soluble salts*.

9. Another third part is put into a florence flask, in which half a gill of equal portions of muriatic acid and water has previously been poured, and which has also been balanced by weights in the scales. After allowing it to stand about three hours, it is ascertained how much less than its former weight is to be added to the weight, in order to balance the flask. It must be remembered that the carbonic acid is to be blowed out of the flask with a bellows, before it is weighed. This is considered as the weight of the carbonic acid that has been expelled. Then by the table of component parts, as 44 is to 56, so is this weight to the weight of the base. The *carbonate of lime* in the soil is thus ascertained. The lime, however, must be subtracted from the silex, and the weight of the carbonic acid must be deducted from the animal and vegetable matter; since the heat that burnt out the animal and vegetable matter, also expelled the carbonic acid, and left the lime with the siliceous soil.

We are aware that part of the quick lime may remain with the soluble salts, and part of the carbonic acid may still remain with its base and the silex. The error, however, will be of no consequence in agriculture.

10. Boil the last third in sulphuric acid, and thus obtain a sulphate of iron. Precipitate the iron with prussiate of potash. Then pour off all

the liquid, dry and weigh the solid blue prussiate of iron. Then by the per cent tables it appears that 30.80 of this salt is protoxid of iron—peroxid being 34.23.

Average specimens of soil from near Albany and Troy, N. Y.

Upland loam. Silex 67 per cent—Alumine 22—Carbonate of lime 1—Soluble salts 1—Decomposed animal and vegetable matter 5—Water 4=100. Settled clear in 4 hours.

Best lowland loam. Silex 56—Alumine 25—Carbonate of lime 2—Soluble salts 1—Decomposed animal and vegetable matter 12—Water 4=100. Settled clear in 3 hours.

Best river alluvion where water stands three or four feet below the surface. Silex 75—Alumine 7—Carbonate of lime 3—Soluble salts 1—Decomposed animal and vegetable matter 11—Water 3=100. Settled clear in 2 hours.

Clay alluvion. Siliceous soil 48—alluminous 39—carbonate of lime 2—soluble salts 2—animal and vegetable matter 5—water 4=100. Settles clear in 26 hours.

Stones and pebbles were included under silex, or siliceous soil, in all these analyses.

Note. If the oxid of iron is sought, most soils will yield from 1 to 3 per cent.

ANALYSIS OF MINERALS.

After the student has prepared or procured the general tests, and applied them in the analysis of Mineral waters, and familiarized himself with their appearances in artificial as well as natural liquids, he should proceed to the analysis of solid minerals.

Most solid minerals must be brought to the liquid state before tests are applied. In many cases a mere mechanical suspension in water will serve the same purpose as a chemical solution.

Analysis of minerals is very properly divided into the *approximating process* and the *proportioning process*.

APPROXIMATING PROCESS.

1. Determine the character of the mineral, as nearly as possible, by the external characters, according to the most approved systems of Mineralogy. Cleaveland and Emmons are the best now in use in this country.

2. Pulverize the mineral in quantities five or six times as great as you intend to analyse; generally about 500 grains. Most minerals, especially those of the silicious kind, require to be heated to a high red heat and plunged into water.

All minerals must be pounded and rubbed very fine. Most failures in analysis may be ascribed to a want of attention to this part of the process. The mineral *must* be so fine as to become somewhat of a paste or cake, when dry.

3. Stir up a little of the powder in pure cold water—let it settle a little, so as to become partly clear. Put a little of this into several wine glasses. Test it separately by hydro-sulphuret of ammonia, nut-galls, prussiate of potash, chromate of potash, oxalic acid, nitrate of silver, muriate of barytes, acetate of lead. Write down the appearance produced by each test; and against each write the name of the mineral substance it indicates, according to the rules set down under general tests.

4. Go through the same process, given under No. 3, with boiling water, if doubts still remain.

5. Go through with same process, given under No. 3, with sulphuric acid, muriatic acid, nitric acid, and nitro-muriatic acid ; unless some, or all, the trials, have demonstrated the presence of all the constituents which can be present in the mineral, without this step.

After this last step has been taken, if a considerable part of the mineral remains in a solid state, proceed as follows :

6. Mix a weighed portion with three times its weight of pure solid potash, and dissolve it in pure water, (or rather stir it up so as to bring it to a kind of mechanical suspension in it.)

7. Put this mixture into a cast-iron crucible (silver or platina would be preferable) and apply heat moderately and stir it continually. Raise the heat a little gradually until all the water is evaporated. Now raise the heat, and keep the mixture red-hot half an hour ; or until the whole, or most of it, becomes liquid. The liquid part is silex. But it is difficult to separate it by pouring. We can only obtain a general knowledge of the mineral by this step. Such as, that if it is mostly liquid and limpid, it is mostly silex—if it is dense, opaque, and paste-like, it contains but little silex—if it is in a pulverized state, it is chiefly alumine.

Thus far we merely approach the desired result. In pursuing the analysis, we depart from the usual complicated method, which takes along every constituent of the specimen at the same time. We find it to be much more simple and convenient to seek the proportion of *each constitu-*

ent of a compound separately, as though it was the only object of research. Then proceed with another specimen of the same mineral upon the same plan; and so on, until every substance, indicated by the tests, be separately ascertained.

PROPORTIONING PROCESS.

8. Having thus, by the aid of mineralogy, and general tests, either ascertained the true character of the mineral, or brought it within narrow limits, we enter upon the necessary analysis for ascertaining the proportional constituents, as follows :

9. In our district of country we are to expect in a specimen some of the following minerals ; and rarely any other :

- | | |
|--|---|
| <p>1. IRON,
 protoxid,
 hematitic,
 argillaceous,
 (lenticular & bog)
 carbonate,
 sulphuret,
 carburet,
 sulphate.</p> <p>2. LEAD,
 galena.</p> <p>3. ZINC,
 blende,
 calamine.</p> <p>4. COPPER,
 pyrites,
 carbonate.</p> <p>5. MANGANESE,
 peroxid,
 argillaceous,</p> | <p>6. CHROME,
 ferriferous,
 oxid of chrome,
 chromate of iron,
 carbonate of chrome</p> <p>7. SILVER,
 sulphuret with lead.</p> <p>8. GOLD.</p> <p>9. BISMUTH.</p> <p>10. COBALT,
 arseniate.</p> <p>11. MOLYBDENA.
 sulphuret.</p> <p>12. ANTIMONY.</p> <p>13. TITANIUM,
 red oxid.</p> <p>14. LIME,
 carbonate,
 sulphate,
 muriate,</p> |
|--|---|

fluates,
phosphates.

15. BARYTES,
sulphate.

16. STRONTIAN,
sulphate.

17. MAGNESIA,
sulphate.

18. SODA,
muriate.

19. POTASH,
nitrate.

20. ALUMINE,
sulphate.

21. SILEX.

22. COAL.

23. BITUMEN.

When the presence of any of these minerals is detected in a specimen under examination, by the external characters given in systems of mineralogy or by the general test, a further analysis may be made as follows :

10. *Iron ore*, whether magnetic, hematitic, argillaceous, or carbonate, should be dissolved in muriatic acid, renewing the acid several times and pouring off the clear liquid, and precipitated by carbonate of soda from the liquid poured off. Dry the precipitate after several washings, and the protoxid is obtained. Or the muriate may be crystallized without precipitation or dried in the amorphous state in a high heat. The tables of the oxids, or salts, will show the exact proportion of pure iron.

N. B. Young analysts generally fail in this analysis, and in some others, because they do not make the powder of the ore fine enough, nor wait long enough for the solution. Nothing but hardened steel is sufficiently hard for a mortar, and from three to six days are required for solution. The steel face of an anvil will be sufficient, if the mineral is pounded in a ring to prevent scattering, with a good smooth-faced hammer.

Pyrites should be boiled in nitric acid until the sulphur is converted into sulphuric acid. The

sulphuric acid is then converted to sulphate of barytes by introducing muriate of barytes; and on drying the precipitated sulphate of barytes the original proportion of sulphur is ascertained—allowing 14.5 of pure sulphur for 100 of this dry precipitate.

Subtract the sulphur, thus ascertained, from the whole mass under examination, and the remainder is the pure iron, if the pyrites is a pure per-sulphuret.

But specimens are rarely pure sulphurets.—Therefore it is best to prove the work by pouring in a solution of carbonate of soda. This precipitate, when dried and weighed, will give the pure iron after deducting the common proportion of oxygen in protoxid of iron.

If manganese is suspected, or any thing else, use tests for their presence respectively. If found present, ascertain their proportions in the usual way with such substances; or precipitate the iron with prussiate of potash, gallic acid, or benzoate of ammonia, and examine the proportion of pure iron in this salt.

Carburet of iron, (plumbago) should be heated in a crucible to a high white heat. The carbon will be burned out, leaving the iron nearly pure.

Sulphate of iron (copperas) should be heated in a crucible to a high white heat. The peroxid of iron will be left in the crucible, which may be weighed in this dry state, and the common deduction made for the oxygen.

2. *Lead*, in the state of a sulphuret, or galena, should be dissolved in diluted nitric acid—the sulphur will be left undissolved. The sulphur must be dried and weighed. This deducted, will probably leave the weight of pure lead. But the

muriate of lead may be dried and weighed, and a deduction made for the proportion of muriatic acid, as set down in the tables. If silver, antimony, or zinc, is suspected, proceed to examine for each independently as directed under these metals.

3. *Zinc*, in the state of a sulphuret, (blende) may be dissolved in nitric acid and precipitated by soda. It is best to re-dissolve it in muriatic acid and precipitate it again. If the presence of copper had appeared by the general test, precipitate it by a plate of clean soft iron.

Calamine may be dissolved in nitric acid and precipitated by ammonia. But it is best to precipitate it and evaporate it to dryness and dissolve it again before it is precipitated for weighing.

4. *Copper pyrites*, may be dissolved by nitromuriatic acid, and precipitated from the acid and from the iron, &c. by the iron plate.

Carbonate of copper, may be dissolved in nitric acid, and the copper precipitated with the iron plate.

5. *Manganese peroxid*, is separated from its oxygen with great difficulty. Its qualities may be tested by making chlorine gas in the usual way, with an ounce of it. See how much pure gas it will produce, and compare it with another ounce which is known to be good.

Argillaceous manganese, is the oxid of manganese combined with iron and clay. Try its quality as above.

Both kinds, on being heated in a gun-barrel, give over carbonic acid, before the heat is raised sufficiently for eliminating oxygen. This may be collected; and, as it is produced from carbonate of iron, the quantity of that ore may thus be ascertained by the tables.

6. *Chromate of iron* must be melted with eight or ten times its weight of potash, and then dissolved in water. This solution should be saturated with nitric acid, to take up the excess of potash. Then put in a solution of nitrate of lead. A double decomposition will take place, and the precipitate will be chromate of lead. After washing and weighing, allow 35 of chromic acid for 100 of chromate of lead.

7. *Sulphuret of silver* is heated with diluted nitric acid. The silver is dissolved. But it is best to heat the residuum to burn off the sulphur; as some silver may still remain with the sulphur residuum.

8. *Gold ores* may be heated with nitro-muriatic acid, and precipitated of a purple colour with muriate of tin.

9. *Bismuth* may be dissolved in nitric acid, and precipitated in the state of a white oxid by mere water.

10. *Cobalt* should be dissolved in nitric acid. It may then be precipitated with ammonia. The precipitate may be dissolved by acetic acid, forming an acetate of cobalt. This metal melted with borax before the blow-pipe or otherwise, produces a smalt-blue glass.

REMARKS.

All the earthy minerals and the remaining ores, found in this district of country, can be analyzed as far as may be required, by attending to the external characters on using the common tests. But if very accurate investigations are required, larger works must be consulted.

EXTEMPORANEOUS EXAMINATIONS OF COMMON SUBSTANCES.

Sulphuric acid blackens a pine stick.

Nitric acid makes a pine stick whitish yellow.

Muriatic acid, if clean, does not colour a pine stick.

Common salt (muriate of soda) when thrown upon burning coals, snaps and gives a yellow flame.

Glauber's salts (sulphate of soda) hisses like water and becomes a compact efflorescence.

Saltpetre (nitrate of potash) roars and gives brilliancy to the coals.

Alum (sulphate of alumine and potash) melts into an inflated efflorescence.

Epsom salts (sulphate of magnesia) becomes a flocculent efflorescence.

Common magnesia (carbonate of magnesia) scarcely changes on ever so hot coals.

White vitriol (sulphate of zinc) snaps somewhat like common salt, but does not give a yellow flame.

Blue vitriol, (sulphate of copper,) if the coals are very hot, it gives a green flame and becomes a white powder.

Copperas (sulphate of iron) extinguishes burning coals and forms brown spots on them.

Sugar of lead (acetate of lead) gives off smoke, but forms no efflorescence.

Corrosive sublimate (per-muriate of mercury) gives a dense suffocating smoke; or if it is dissolved in water and poured into lime-water, it gives an orange coloured precipitate.

Calomel, if dropped into a solution of pearlash, gives a dark precipitate; but will not give the orange colour to lime water.

Verdegris (acetate of copper) on being held in the flame of a candle, presents numerous red globules.

Borax (sub-borate of soda) on being held in the flame of a candle, boils, swells, and becomes like parched corn. This salt gives a sweetish taste.

Iron, if dissolved in warm sulphuric acid, gives a black colour when dropped into an infusion of nut-galls.

Manganese (in its common state of a peroxid) if pulverized, mixed with common salt, and made into a thin paste; then put into a wine glass, and sulphuric acid is poured upon it, a suffocating gas of a light green colour will be given off. If a piece of calico is wet and spread over the top of the glass, the colour of the calico will soon be extinguished.

Tin dissolved in nitro-muriatic acid changes a purple solution of cochineal to scarlet.

Zinc, on being melted and boiled, becomes a white woolly substance, lighter than air.

Common arsenic (arsenious acid) gives the smell of garlick, when thrown upon hot coals.

Copper, if dissolved in sulphuric acid, becomes blue when dropped into liquid ammonia.

Common sulphuret of antimony, if pulverized and mixed with saltpetre and thrown upon a fire-shovel heated to whiteness, deflagrates and becomes a yellow mass.

Bismuth, if dissolved in nitric acid, is precipitated in a white powder if water is added.

Gold can be dissolved in no acid, but the nitro-muriatic, and is of a yellow colour.

Platina can be dissolved in no acid but nitro-muriatic, and is of a steel grey colour.

Silver can be dissolved in no single acid but the nitric ; and when the solution has become clear, a particle of common salt will render it cloudy.

Mercury, if dissolved in cold nitric acid, will throw down a white insoluble powder (calomel) if a solution of common salt be poured into it.

Lead, if dissolved in hot nitric acid, becomes black by pouring into it water which is charged with sulphuretted hydrogen.

The following metals, when forming the bases of salts, may be dissolved in pure water, and then detected by their various coloured precipitates, which are produced by pouring in a solution of prussiate of potash.

Iron will give a blue precipitate—manganese, peach-bloom—tin, white—zinc, white—chrome, green—columbium, olive—bismuth, white—cobalt, grass-green—titanium, yellowish-brown—cerium, white—uranium, blood-red—silver, white becoming blue—palladium, olive—iridium, colourless—lead, white—nickel, milk-white—protoxid of copper, reddish-brown, and peroxid of copper, white.

TABLES.

APOTHECARIES' WEIGHT.

20 grains 1 scruple—3 scruples 1 drachm—3 drachms 1 ounce—12 ounces 1 pound.

MARKS ON WEIGHTS.

o stands for grain— $\mathfrak{z}$ for scruple— $\mathfrak{d}$ for drachm— $\mathfrak{ss}$ for ounces— $\mathfrak{lb}$ for pound—i or j for one of either, ii for two, &c.

FRENCH WEIGHTS.

A millegramme is equal to .0154 of a grain—a centigramme, 0.1544 gr.—a decigramme, 1.5444 gr.—a gramme, 15.4440 gr.—a decagramme, 154.4402 gr.—a hecatogramme, 1544.4023 gr.—a kilogramme, 15444.0234 gr.—a myriogramme, 154440.2344 gr.

WEIGHT OF GASES.

Atmospheric air being assumed as the standard or unity, 100 cubic inches, weighing 30 grains and 20 hundredths of a grain. Atmospheric air, 1.000—oxygen, 1.117—nitrogen, 0.968—hydrogen, 0.074—carbonic acid gas, 1.542—ammonia, 0.596—sulphuretted hydrogen, 1.192—carburetted hydrogen, (olifiant) 0.998—coal gas, 0.450—phosphuretted hydrogen, 0.894—chlorine, 2.495—muriatic acid, 1.285—nitrous oxid, (exhilarating gas) 1.527—nitric oxid, 1.043—nitrous acid, 2.135—sulphurous acid, 2.235—prussic acid, (hydrocyanic) 0.946—water in vapour, 0.623—alcohol in vapour, 1.500—sulphuric ether in vapour, 2.396—spirits of turpentine in vapour, 5.013.

WEIGHT OF LIQUIDS.

Water being assumed as the standard or unity.

Sulphuric ether, 0.76—nitric ether, 0.90—alcohol, 0.

31—proof spirits, 0.93—distilled vinegar, 1—muriatic acid, concentrated, 1.17—sulphuric acid, 1.84—nitric acid, 1.42—fuming nitrous and nitric acid, 1.50.

WEIGHT OF SOLIDS.

Water being assumed as the standard or unity.

Potassium, 0.85—sodium, 0.97—lime, 2.3—barytes, 4—strontian, 3.7—magnesia, 2.3—silex, 2.66—alumine, 2—iron, 7.78—manganese, 6.85—tin, 7.3—zinc, 7—cadmium, 8.6—arsenic, 9.35—chrome, 5.9—molybdena, 7.4—tungsten, 17.5—columbium, 5.91—copper, 8.9—antimony, 6.7—bismuth, 9.8—cobalt, 8—red oxid of titanium, 4.2—tellurium, 6.1—red oxid of cerium, 4.9—uranium, 9.—gold, 19.3—silver, 10.5—platina, 21.—palladium, 11.—rhodium, 11.—iridium, 19.5?—osmium, unknown—mercury, 13.5—lead, 11.35—nickel, 8.25.

SIMPLE AFFINITIES.

Each substance, printed in small capitals, has the strongest affinity for the substance standing next to it, and this force is weaker for the next, and so in succession.

OXYGEN. Carbon, manganese, zinc, iron, tin, antimony, hydrogen, phosphorus, sulphur, arsenic, nitrogen, nickel, cobalt, copper, bismuth, mercury, silver, gold, platina, muriatic acid.

OXYGEN. [Set down according to the difficulty with which it is separated from metals, by heat, when combined by nature.]

Titanium, manganese, zinc, iron, tin, molybdena, cobalt, antimony, nickel, arsenic, chrome, bismuth, lead, copper, platina, mercury, silver, gold.

CARBON. Oxygen, iron, hydrogen.

NITROGEN. Oxygen, sulphur? phosphorus, hydrogen.

HYDROGEN. Chlorine? oxygen, sulphur, carbon, phosphorus, nitrogen.

SULPHUR, PHOSPHORUS? Potash, soda, iron, copper, tin, lead, silver, bismuth, antimony, mercury, arsenic, molybdena.

POTASH, SODA and AMMONIA. *Acids.* Sulphuric, nitric, muriatic, phosphoric, fluoric, oxalic, tartaric, arsenic, citric, benzoic, sulphurous, acetic, boracic, carbonic, prussic, oil, water, sulphur.

BARYTES. Sulphuric, oxalic, fluoric, phosphoric, nitric, muriatic, citric, tartaric, arsenic, benzoic, boracic, carbonic, prussic.

STRONTIAN. Sulphuric, phosphoric, oxalic, tartaric, fluoric, nitric, muriatic, carbonic.

LIME. Oxalic, sulphuric, tartaric, phosphoric, nitric, muriatic, fluoric, arsenic, citric, malic, benzoic, boracic, carbonic, prussic, sulphur, phosphorus, water, fixed oil.

MAGNESIA. Oxalic, phosphoric, sulphuric, fluoric, nitric, muriatic, tartaric, citric, benzoic, acetic, boracic, carbonic, prussic, sulphur.

ALUMINE. Sulphuric, nitric, muriatic, oxalic, fluoric, tartaric, citric, phosphoric, benzoic, acetic, boracic, carbonic, prussic.

SILEX. Fluoric, potash.

OXID OF PLATINA, OXID OF GOLD. Gallic, muriatic, nitric, sulphuric, arsenic, fluoric, tartaric, phosphoric, acetic, prussic, ammonia.

OXID OF SILVER. Gallic, muriatic, oxalic, sulphuric, phosphoric, nitric, arsenic, fluoric, tartaric, citric, acetic, prussic, carbonic.

OXID OF MERCURY. Gallic, muriatic, oxalic, arsenic, phosphoric, sulphuric, tartaric, citric, malic, nitric, fluoric, acetic, benzoic, boracic, prussic, carbonic.

OXID OF LEAD. Gallic, sulphuric, oxalic, arsenic, tartaric, phosphoric, muriatic, nitric, fluoric, citric, malic, acetic, benzoic, boracic, prussic, carbonic, fixed oils, ammonia.

OXID OF COPPER. Gallic, oxalic, tartaric, muriatic, sulphuric, nitric, arsenic, phosphoric, fluoric, citric, acetic, boracic, prussic, carbonic, fixed alkalies, ammonia, fixed oils.

OXID OF ARSENIC. Gallic, muriatic, oxalic, sulphuric, nitric, tartaric, phosphoric, fluoric, citric, acetic, prussic, fixed alkalies, ammonia, fixed oils, water.

OXID OF IRON. Gallic, oxalic, tartaric, camphoric, sulphuric, muriatic, nitric, phosphoric, arsenic, fluoric, citric, acetic, boracic, prussic, carbonic.

OXID OF TIN. Gallic, muriatic, sulphuric, oxalic, tartaric, arsenic, phosphoric, nitric, fluoric, citric, acetic, boracic, ammonia, prussic.

OXID OF ZINC. Gallic, oxalic, sulphuric, muriatic, nitric, tartaric, phosphoric, citric, fluoric, arsenic, acetic, boracic, prussic, carbonic, fixed alkalies, ammonia.

OXID OF ANTIMONY. Gallic, muriatic, benzoic, oxalic, sulphuric, nitric, tartaric, phosphoric, citric, fluoric, arsenic, acetic, boracic, prussic, fixed alkalies, ammonia.

SULPHURIC ACID, PRUSSIC. Barytes, strontian, potash, soda, lime, magnesia, ammonia, alumine, metallic oxids.

PHOSPHORIC ACID, CARBONIC. Barytes, strontian, lime, potash, soda, ammonia, magnesia, (attracts car. stronger than ammo.) alumine, metallic oxids.

NITRIC ACID, MURIATIC. Barytes, potash, soda, strontian, lime, magnesia, ammonia, alumine, metallic oxids.

FLUORIC ACID, BORACIC, ARSENIC. Lime, barytes, magnesia, potash, soda, ammonia, alumine, silex.

ACETIC ACID, LACTIC. Barytes, potash, soda, lime, ammonia, magnesia, metallic oxids, alumine.

OXALIC ACID, TARTARIC, CITRIC. Lime, barytes, strontian, magnesia, potash, soda, ammonia, alumine, metallic oxids, water, alcohol.

BENZOIC ACID. White oxid of arsenic, potash, soda, ammonia, barytes, lime, magnesia, alumine.

FIXED OILS. Lime, barytes, potash, soda, magnesia, oxid of mercury, other metallic oxids, alumine.

ALCOHOL. Water, ether, volatile oil, alkalies, sulphurets.

SULPHURETTED HYDROGEN. Barytes, potash, soda, lime, ammonia, magnesia.

PROPORTIONS OF ELEMENTARY CONSTITUENTS.

BINARY COMPOUNDS.

The oxygen 10 in all, excepting ammonia.

Water, 1.32 hydrogen—carbonic acid, 3.77 carb.—sulphuric acid, 6.66 sulphur—phosphoric acid, 8.7 phos.—nitric acid, 3.51 nit.—chlorine, 31.1 mur. acid—ammonia, 17.54 nit. 396 hyd.—soda, 29.1 sodium—potash, 49.1 potassium—magnesia, 14.6 magnesium—lime, 25.46 calcium—red oxid of iron, 23 iron—green oxid of iron, 34.5 ir.—black oxid of copper, 40 copper—oxid of zinc, 41 zinc—red oxid of mercury, 125.5 merc.—black oxid of mercury, 251 merc.—litharge, 129.5 lead—oxid of silver, 135 silver.

TERNARY COMPOUNDS.

Subcarbonate of ammonia, 27.5 acid to 21.5 am.—subcarbonate of soda, 27.5 carb. ac. to 39.1 soda—subcarbonate of potash, 27.5 acid to 59.1 potash—carbonate of lime, 27.54 carb. acid to 35.46 lime—carbonate of barytes, 27.5 acid to 97 barytes—sulphate of soda, 50 acid to 39.1 soda—sulphate of magnesia (dry) 50 acid to 24.6 magn.—ditto chrystallized, 74.6 sul. mag. to 79.3 water—sulphate of barytes, 50 acid to 97 barytes—sulphate of copper, 50 acid to 50 copper to 56.6 water—sulphate of iron, 50 acid to 34.5 iron to 79.3 water—sulphate of zinc, 50 acid to 51 zinc to 79.3 water—nitrate of potash, 67.54 acid to 59.1 potash—muriate of ammonia, 34.1 acid to 21.5 am. to 11.32 water—muriate of soda, 34.1 acid to 39.1 soda—muriate of potash, 34.1 acid to 59.1 potash—oxymuriate of potash 93.2 mur. pot. to 60 ox.—muriate of lime, 34.1 acid to 35.5 lime—muriate of barytes, 34 acid to 97 barytes—cor. muriate of mercury, 34.1 acid to 10 ox. to 125.5 merc.—submuriate of ditto, 34 acid to 10 ox. to 251 merc.—sulphate of lime (dry) 50 acid to 35.5 lime—ditto crystallized, 85.5 sul. lime to 22.4 water.

EFFECTS OF HEAT AT THE DIFFERENT DEGREES OF FAHRENHEIT.

90 degrees (*below zero*) the greatest degree of artificial cold—55 nitric acid freezes—50 natural cold at Hudson's Bay—46 ether? and strong liquid ammonia freeze—39 mercury freezes—36 sulphuric acid freezes—0 cold produced by equal parts of snow and salt—25 (*above zero*) human blood freezes—30 milk freezes—32 water and oxymuriatic acid freezes—67 water boils in a vacuum—97 lard melts—98 blood heat, ether boils—107 feverish heat—122 phosphorus burns—127 tallow melts—142 beeswax melts—176 alcohol boils—212 water boils—442 tin melts—476 bismuth melts—540 arsenic is volatilized—590 sulphuric acid boils—612 lead melts—644 mercury boils—700 zinc melts—809 antimony melts—1077 iron red by daylight—1892 silver melts—2205 copper melts—2517 gold melts—6508 iron welding hot—8696 cast iron melts—10517 manganese melts—11454 soft iron melts—23177 platina melts.

ATOMIC THEORY.

RELATIVE WEIGHT OF ATOMS.

Mr. Dalton has shewn, that if the weight of the ultimate indivisible atom of oxygen be called one, the weight of the ultimate atoms of the following substances are proportioned to it as here set down. Oxygen 1---nitrogen 1.8---hydrogen 0.13---carbon 0.75---phosphorus 2.6---sulphur 2---chlorine (if simple) 4.5---potassium 6---sodium 5.88---calcium 2.6---barium 8.7---magnesium 1.5---gold 24.9---platina 12.1---silver 13.7---mercury 25---copper 8---iron 7.1---tin 14.7---lead 12.9---zinc 4---bismuth 9---antimony 11.2---arsenic 6---manganese 7.1.

NUMBER OF CONSTITUENT ATOMS IN COMPOUND SUBSTANCES.

Acids.

Water, 1 ox. 1 hyd.---carbonic acid, 2 ox. 1 car.---oxid of nitrogen, 1 ox. 1 nit.---nitrous acid, 3 ox. 1 nit.

---nitric, acid 5 ox. 1 nit.---phosphoric acid, 3 ox. 1 phos.
 ---sulphurous acid, 2 ox. 1 sul.---sulphuric acid, 3 ox. 1
 sul.---oxalic acid, 3 ox. 2 carbon and hydrogen.

Alkalies.

Potash, 1 potassium 1 ox.---soda 1 sodium 2 ox.---am-
 monia, 1 nitrogen 1 hydrogen---lime, 1 calcium 1 ox.---
 magnesia, 1 magnesium 1 ox.---barytes, 1 bar. 1 ox.

Oxids of Metals.

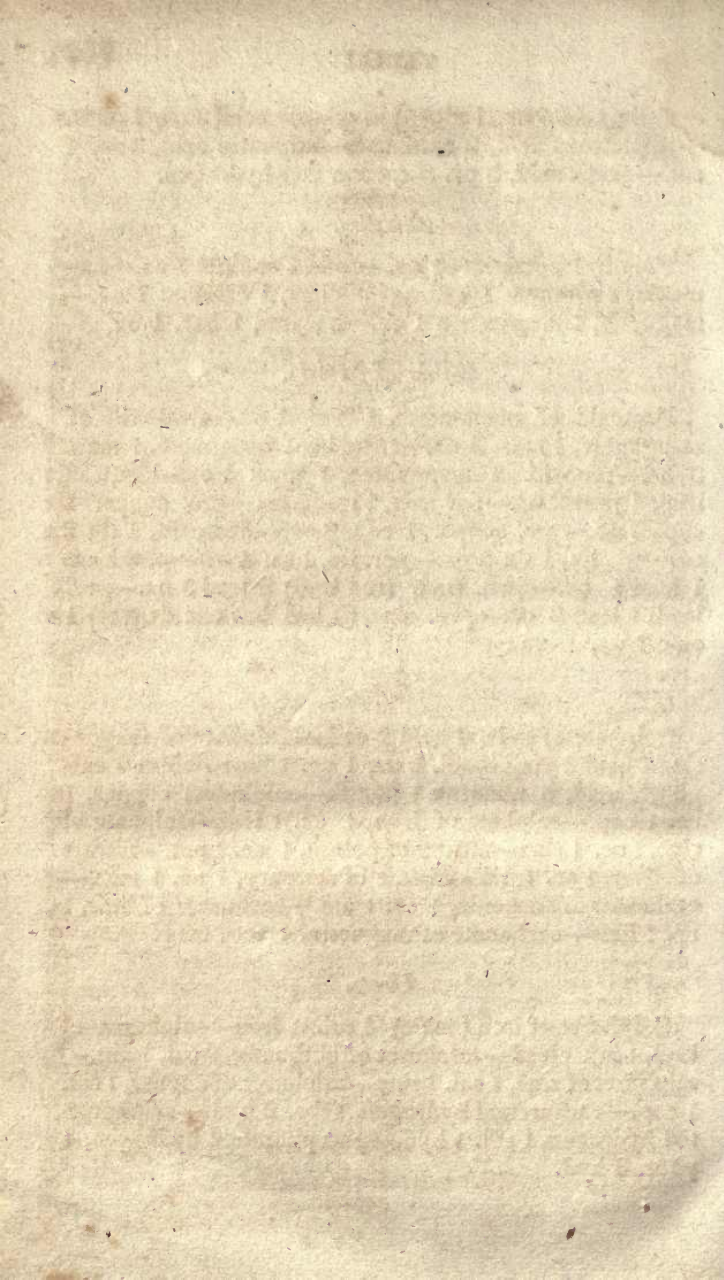
Protoxid of manganese, 1 man. 1 ox.---deutoxid of
 manganese, 1 man. 2 ox.---tritoxid of manganese, 1 man.
 3 ox.---peroxid of manganese, 1 man. 4 ox.---deut. of
 iron, 1 iron 2 ox.---per iron, 1 iron 3 ox.---pro. copper, 1
 cop. 2 ox.---per. copper, 1 cop. 2 ox.---deut. tin, 1 tin 2
 ox.---tri. tin, 1 tin 3 ox.---per. tin, 1 tin 4 ox.---pro. lead,
 1 lead 1 ox.---deut. lead, (red lead) 2 lead 3 ox.---per.
 lead, 1 lead 2 ox.---pro. zinc, (it has but one degree) 1
 zinc 1 ox.

Salts.

Sulphate of soda, 1 acid 2 soda---sulphate of magne-
 sia, 1 acid 1 mag.---sul. lime, 1 ac. 1 lime---alum 6 sul-
 phuric acid, 5 alumine 1 potash---sulphate of copper, 1
 ac. 1 cop.---sulphate of iron, 1 ac. 1 iron---sulphate of
 zinc, 1 ac. 1 zinc---nitrate of potash, 1 ac. 1 pot.---nitrate
 of silver, 1 ac. 1 sil.---nitrate of mercury, 1 ac. 1 mer.---
 carbonate of ammonia, 1 ac. 1 am.---carbonate of lime, 1
 ac. 1 lime---carbonate of magnesia, 1 ac. 1 mag.

Urets.

Sulphuret of iron (cubic) 4 sul. 1 iron---sulphuret of
 lead, 1 sul. 1 lead---sulphuret of antimony, 2 sul. 1 ant.---
 sulphuret of zinc, 1 sul. 1 zinc---sulphuret of copper, 1 sul.
 1 cop.---carburetted hydrogen, 1 car. 2 hyd.---sulphurett-
 ed hydrogen, 1 sul. 1 hyd.---phosphuretted hydrogen, 1
 phos. 3 hyd.



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ADDITIONS AND CORRECTIONS.

Directions for making *White Flux* and *Black Flux*.

[Make a reference to this with a pencil at p. 247.]

White flux. Mix equal parts by weight of saltpetre and cream of tartar (supertartrate of potash) and pulverize the mixture very fine. Heat a crucible to a high red, or to a white, heat. Drop into the hot crucible a teaspoon of the mixture at a time. A detonation will ensue at every introduction of the mixture. The tartaric and nitric acids will mostly fly off, leaving potash almost pure. This must be closely corked up in a vial, to be used for aiding in the fusion of some minerals, &c. when no oxygen is to be disengaged.

Black flux. Mix saltpetre with double its weight of cream of tartar, and pulverize the mixture. Drop this mixture into the hot crucible as directed in making white flux. In this case some of the tartaric acid will be decomposed and charcoal produced in very intimate combination with potash. This must be closely corked up in a vial, to be used when oxygen of a metallic oxid is to be disengaged by its combination with the charcoal, while the potash assists the process of fusion.

Spelling.—Sufficient attention has not been given, in this book, to uniformity in spelling. We have authorities for difference in spelling several technical names. As chlorin or chlorine, oxigen, oxygen, or oxygene. Some one of the authorized kinds of spelling ought to have been selected, and pursued uniformly.

Page 14—line 16, "or" should be of, and be preceded by a comma.

— 32—line 3 from the bottom, "liquids" should be solids.

— 35—line 14 and 15, a comma must be placed after the words "scratch" and "smoke."

— 102—line 5 from the bottom, "Prop. 7." should be Prop. 8.

— 119—line 8 from the bottom, "soluble" should be globule.

— 247—line 7, "vegetade" should be vegetable. On the same page, after the word "blow-pipe" add, See Additions and Corrections, p. 275.

Eaton's Manual of Botany.

A fifth edition of this work will soon be through the press of Messrs. WEBSTERS and SKINNERS. It will embrace all known indigenous plants growing north of the Gulf of Mexico, and the common cultivated exotics.

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